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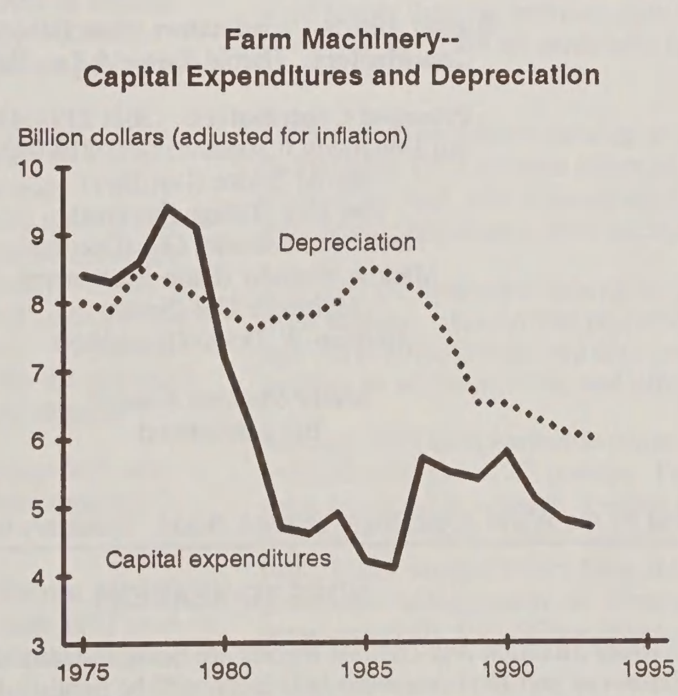
Inputs

Situation and Outlook Report



FINAL ISSUE
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NOTE TO READERS

The *Agricultural Resources Situation and Outlook* reports are being discontinued with this issue. Instead, an annual report, *Agricultural Resources and Environmental Indicators*, will be published and will contain most of the information currently included in the *Agricultural Resources Situation and Outlook* reports. The first issue is scheduled for June 1994. By combining data and information into one annual report, ERS will be able to provide a more comprehensive view of resource and technology issues and trends.

Summary

Harvested Cropland Expected To Be Lowest Since 1988.

Cropland used for crops and harvested in 1993 is estimated to be the lowest since 1988. This decline results largely from wet weather and flooding in the Corn Belt, Lake States, and Northern Plains, which led to the smallest planted acreage since 1988. Preliminary estimates indicate the highest crop failure since the 1950's. Based on program sign-up in March and April, slightly more land was idled in Federal programs than last year. However, due to the weather and floods, the program certification date was moved to September 17 in designated disaster counties and the final 1993 program compliance may differ significantly from early-season plans.

The effects of Midwestern flooding and Southeastern drought have affected input use, however, the magnitude is still uncertain.

The amount of applied inputs was less than in previous years due to reduced planted acreage. Inputs applied after planting were also reduced. In addition, capital equipment was lost in the flooding.

U.S. fertilizer supplies during 1994 are expected to be ample, at stable to slightly higher prices. Planted acreage of the major fertilizer-using crops will primarily determine usage. Plant nutrient use in 1992/93 is estimated at 19.8 million tons, down over 4 percent from a year earlier. Further evaluation of the Midwest flood impact could dampen this estimate. Political and economic restructuring in Eastern Europe, China, India, the former USSR, and the Middle East will likely reduce projected world fertilizer production and consumption in 1992/93.

Conservation tillage systems were used on about 18 percent of the 1993 harvested winter wheat acreage. Nearly 76 percent of the acreage was conventionally tilled without the moldboard plow. This is common in the wheat-fallow rotations of the arid west and is done primarily with the chisel plow, which leaves residue on the soil surface. Use of the moldboard plow continued to decrease -- 7 percent in 1993 compared to 11 percent in 1992. No-till increased from 3 to 4 percent and mulch-till decreased slightly.

Over 90 percent of the 1992 fall potato acreage was conventionally tilled. Very little change has been reported since 1989.

U.S. farmers can expect energy prices for the rest of 1993 and for 1994 to be at, or modestly above, their 1992 averages due to no or, at most, a small expected price increase for imported crude oil. For 1993, direct energy expenditures are likely to be 3 to 4 percent below the preceding year. This reduction is attributed to a decline in energy use due to a drop in planted acreage resulting from the Midwest flooding, as well as the steady to minimally higher energy prices.

Capital investment in farm machinery increased during the first 8 months of 1993. Farm tractor purchases were up 10 percent and combine purchases were up 15 percent, compared to 1992. However, both were still below 1991.

Several demand factors were responsible for increased capital investment in farm machinery. Farm income was up 20 percent in 1992, largely due to bumper grain crops. Since machinery purchases tend to lag behind farm income, the income increase led to more purchases in 1993. Interest rates are below 1992 levels, another positive factor for increased purchases. Higher asset values and lower farm debt increased farmers' equity position, which also contributed to higher demand for farm machinery. Nationally, capital depletion is continuing, with real depreciation exceeding real capital expenditures every year since 1980.

In the 1992/93 crop year, total seed use for eight major crops remained unchanged from the previous year at 5.9 million tons. In 1993, soybean planted acreage stayed the same and the increased barley, oats, and cotton planted acreage was offset by decreased corn, sorghum, and rice.

In 1993, field seed and forage seed prices paid by farmers were higher than the previous year. As a result, USDA's price-paid index for all seeds rose to 169 in 1993 from 165 in 1992.

Farm seed expenditures were up in 1992 and are likely to be higher in 1993 because prices of most field crops and small grain seed, which constitute the major component of total seed expenditures, have increased sharply.

The U.S. net seed-trade balance in 1992 fell 8 percent to $468 million. This decline primarily reflects gains in forage, vegetables, flower, and corn seed import values and declines in soybeans, corn, and other seed export values.

Average 1993 farm herbicide prices rose 1.9 percent and insecticide prices rose 7.7 percent. Pesticide manufacturers' costs increased in order to develop additional data to reregister older products, and to research and develop new products. Many manufacturers have also embarked on expensive biotechnology research. Dealers' costs have also risen, especially for liability insurance.

Cropland Harvested Is Down, Crop Failure Is Up, and Land Idled in Federal Programs Is Up Slightly

Cropland harvested is down an estimated 9 million acres in 1993 and cropland used for crops is down about 6 million acres. Land idled in Federal programs and crop failure is up from 1992.

Farmers intend to harvest nearly 297 million acres of the principal crops in 1993, which together with minor crops may raise total harvested acres to more than 309 million. About 10 million acres of the total harvested are estimated to be double cropped. After allowing for double cropping, harvested cropland is expected to be 299 million acres (table 1). This estimate of land from which crops will be harvested is about 9 million acres below last year and the smallest area since 1988. The reduction is the result of a higher crop failure, more land idled in Federal programs, and, perhaps most importantly, a smaller acreage planted.

Crop failure is estimated to be more than 13 million acres, or more than 4 percent of the planted acreage. This is larger than 1988, when severe drought devastated several regions and is the highest estimated crop failure since the 1950's. The expected crop failure from drought in some regions and from wet weather and flooding in others reflects sharp regional changes from last year. These include much higher crop failure in the Corn Belt, Lake States and Appalachian regions, followed by the Delta States, Northern Plains, and Southeast regions. Crop failure in 1993 is estimated to be less than last year for the Southern Plains, Mountain, and Pacific regions (table 2). Continued wet weather in the north central United States and/or killing frosts prior to crop maturity may further reduce acres harvested. Also, the impact of the drought in the Southeast and Appalachian regions may be underestimated.

An estimated 22 million acres were summer fallowed in 1993, down about a million acres from 1992 (table 1). It is likely that some of the additional land contracted into the Conservation Reserve Program (CRP) for 1993 was normally summer fallowed. Lower set-aside requirements for some program crops, especially wheat, also has contributed to the decline in land summer fallowed since 1987.

The 334 million cropland acres used for crops (cropland harvested, crop failure, and summer fallow) in 1993 are down about 6 million (1.8 percent) from 1992 (table 1). This is the smallest area used for crops since 1988. The decrease in estimated cropland used for crops reflects primarily the prevented plantings.

Land idled by Federal programs last year decreased to about 55 million acres, the lowest since 1986 (table 1, figure 1). According to the 1993 program enrollment report there was a slight increase in cropland idled in Federal programs. The largest portion of the 1992-93 increase in land idled, however, was the result of more than 1 million additional acres being newly enrolled in the CRP.

Cropland Decreases in 6 of the 10 Farm Production Regions in 1993

Cropland used for crops in 1993 is lower than last year in 6 of the 10 farm production regions (table 2, figure 2). Cropland used and harvested decreased the most in the Lake States, Corn Belt and Northern Plains. Cropland harvested is estimated to be down 10.0, 6.7, and 3.5 percent, respectively, in these regions from last year due to increased crop failure and to prevented plantings because of wet conditions and flooding. Cropland used for crops is estimated to be down more than 4 percent in the Lake

Table 1--Major uses of cropland, United States 1/

Cropland	1984	1985	1986	1987	1988	1989	1990	1991	1992 2/	1993 2/
					Million acres					
Cropland used for crops	373	372	357	331	327	341	341	337	340	334
Cropland harvested 3/	337	334	316	293	287	306	310	306	308	299
Crop failure	6	7	9	6	10	8	6	7	9	13
Cultivated summer fallow	30	31	32	32	30	27	25	24	23	22
Cropland idled by all Federal programs	27	31	48	76	78	61	62	65	55	56
Annual programs	27	31	46	60	53	31	28	30	20	20
Long-term programs	0	0	2	16	25	30	34	35	35	36
Total, specified uses 4/	400	403	405	407	405	402	403	402	395	390

1/ Includes the 48 conterminous States. Fewer than 200,000 acres were used for crops in Alaska and Hawaii.
2/ Preliminary, subject to revision. 3/ A double-cropped acre is counted as one acre. 4/ Does not include cropland pasture or idle land not in Federal programs that is normally included in the total cropland base. Breakdown may not add to totals due to rounding.

States and nearly 3 percent in the Corn Belt and Northern Plains. The Delta States, Southeast, and Southern Plains also experienced less cropland used for crops this year than in 1992.

The decrease in cropland acres in the Lake States resulted primarily from decreases in corn, soybeans, wheat, and oats (table 7). In the Corn Belt, cropland decreased primarily due to less corn and soybeans, with small decreases in acreage of oats and sorghum. Corn Belt wheat was estimated to increase in 1993. The Northern Plains experienced decreases in corn, soybeans, sorghum, barley, and oats. The acreage of wheat was also up slightly in the Northern Plains in 1993.

Idled Acreage Higher Than 1992; Lower Than Other Years Since 1986

About 56.4 million acres were intended to be idled under Federal programs this year (table 3). However, the 1993 annual program data is from the June report of program sign-up by farmers in March and April. As a result of the extreme weather conditions in several regions; the extended period for participation in the 0/92 program; and other disaster relief programs, actual program participation this year may be quite different. The sign-up period for the 0/92 program was extended to September 17 in designated disaster areas.

The preliminary estimates of land idled by Federal programs excludes an additional 1.0 million acres of feed grain and wheat base that were signed up under 0/92 or 50/92 provisions, but were intended to be planted to minor

Figure 1

Major Uses of U.S. Cropland

Million acres

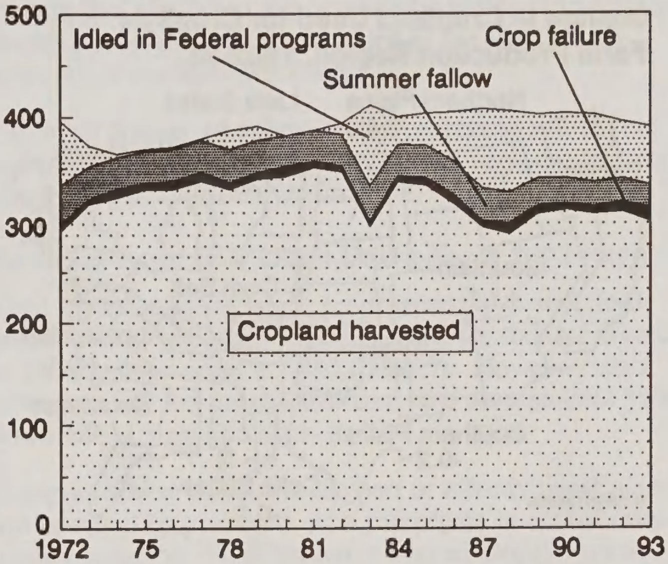


Table 2--Cropland used for crops in 1993, and 1992-93 change, by region

Region	Cropland used for crops 1/: Cropland harvested	Crop failure	Summer fallow	Total	Share of all cropland used for crops
1993:	Million acres				Percent
Northeast	10.9	0.3	-	11.2	3.3
Lake States	30.6	2.5	-	33.1	9.9
Corn Belt	75.8	3.7	-	79.5	23.8
Northern Plains	72.6	2.8	10.7	86.1	25.7
Appalachian	16.0	0.8	-	16.8	5.0
Southeast	9.4	0.6	-	10.0	3.0
Delta States	15.6	0.4	-	16.0	4.8
Southern Plains	28.1	1.3	0.8	30.2	9.0
Mountain	24.8	0.5	8.0	33.3	10.0
Pacific	15.6	0.2	2.5	18.3	5.5
United States 2/	299.4	13.1	22.0	334.5	100.0
1992-93 change:	Percent				
Northeast	1.9	3/	3/	1.8	
Lake States	-10.0	257.1	3/	-4.6	
Corn Belt	-6.7	428.6	3/	-2.9	
Northern Plains	-3.5	55.6	-7.8	-2.7	
Appalachian	-1.8	166.7	3/	0.6	
Southeast	-2.1	20.0	3/	-1.0	
Delta States	-2.5	100.0	3/	-1.2	
Southern Plains	8.1	-61.8	-20.0	-0.7	
Mountain	6.0	-37.5	-1.2	3.4	
Pacific	3.3	-33.3	-7.4	1.1	
United States 2/	-2.6	45.6	-5.6	-1.6	

- = None or fewer than 50,000 acres.
1/ Preliminary. Based on farmers' intentions to harvest. 2/ Includes the 48 conterminous States. Fewer than 200,000 acres were used for crops in Alaska and Hawaii. Breakdown may not sum to totals due to rounding.
3/ No change or less than 0.05 percent.

oilseeds as permitted by the 1990 Farm Act. Only about one in three of the 1993 idled acres--19.9 million--is in annual Federal acreage reduction programs (including the 0/92 and 50/92 programs not planted to minor oilseeds). Nearly two out of three of the 1992 idled acres are enrolled in the CRP.

Figure 2

Change in Cropland Used for Crops by Farm Production Region, 1992-93

In million acres.

Continuing the pattern from 1987-90, fewer acres of most program crops were idled by annual crop programs in 1993 than in 1990 (table 3). The pattern of crop idling over the 1991-93 period is somewhat mixed. However, except for last year, fewer acres were idled by the annual crop programs than in any other year since 1982. Only corn and rice had more acres idled in annual crop programs in 1993 than 1992. This is the result of increased acreage reduction program (ARP) requirements this year from 5 to 10 percent for corn and from 0 to 5 percent for rice.

ARP requirements remained the same as last year for sorghum (5 percent) and oats (0 percent) but decreased for barley (from 5 to 0 percent), wheat (from 5 to 0 percent), and upland cotton (from 10 to 7.5 percent). The wheat ARP has also been set at 0 percent for 1994. The feed grain program for 1994 set preliminary ARP levels at 5 percent for corn and 0 percent for sorghum, barley, and oats. These feed grain ARP levels are subject to revision until November 15.

The higher corn ARP for 1993, with other program provisions for each feed grain crop, resulted in a program sign-up for an increased feed-grain base idling of 3.5 million acres above the 20.8 million idled in 1992 (including the CRP) (table 3). With the decline in ARP and participation in other program provisions, wheat base idled is estimated

Table 3--Cropland idled under Federal acreage reduction programs, United States

Program and crop	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993 1/
					Million acres					
Annual programs, base acres:										
Corn	3.9	5.4	14.2	23.2	20.5	10.8	10.7	7.4	5.2	8.8
Sorghum	0.6	0.9	2.9	4.1	3.9	3.3	3.3	2.4	2.0	2.0
Barley	0.5	0.7	2.0	3.0	2.8	2.3	2.9	2.1	2.3	1.9
Oats	0.1	0.1	0.5	0.8	0.3	0.3	0.2	0.5	0.6	0.6
Wheat	18.6	18.8	21.0	23.9	22.5	9.6	7.5	15.6	7.3	4.6
Cotton	2.5	3.6	4.0	3.9	2.2	3.5	2.0	1.2	1.7	1.3
Rice	0.8	1.2	1.5	1.6	1.1	1.2	1.0	0.9	0.4	0.6
Total, annual programs 2/	27.0	30.7	46.1	60.5	53.3	30.9	27.7	30.1	19.5	19.9
Conservation Reserve Program (CRP), base acres: 3/										
Corn			0.2	2.3	2.8	3.4	3.8	3.9	4.1	4.3
Sorghum			0.2	1.2	1.9	2.2	2.4	2.4	2.4	2.5
Barley			0.1	1.1	1.9	2.4	2.7	2.8	2.8	2.8
Oats			0.1	0.5	0.9	1.1	1.3	1.3	1.4	1.4
Wheat			0.6	4.2	7.1	8.8	10.3	10.4	10.6	10.9
Cotton			0.1	0.7	1.0	1.2	1.3	1.3	1.4	1.4
Rice			4/	4/	4/	4/	4/	4/	4/	4/
Total CRP-idled base acres 2/			1.2	10.0	15.5	19.0	21.8	22.0	22.6	23.3
Total base acres idled 2/	27.0	30.7	47.4	70.5	68.8	49.9	49.5	52.1	42.1	43.2
Total CRP-idled nonbase acres			0.7	5.7	8.9	10.9	12.1	12.4	12.8	13.2
Total cropland idled under Federal programs 2/	27.0	30.7	48.1	76.2	77.7	60.8	61.6	64.5	54.9	56.4

1/ Preliminary. Annual program data based on the June ASCS Program Enrollment Report compiled from farmer's sign-up in March and April. 2/ Because of rounding, crop acreages may not sum to the totals. Base acreages idled under 0/92 and 50/92 programs from 1986 through 1992 are included in annual program data. However, base acres of feed grains and wheat enrolled in 0/92 and planted to oilseeds in 1991 (0.5 million acres), in 1992 (0.7 million acres), and in 1993 (1.0 million acres) are not included. 3/ Program began in 1986. Small acreages of peanut and tobacco base were bid into the CRP in addition to the crops listed. 4/ Less than 50,000 acres.

to be down 2.4 million acres from the 17.9 million idled last year in the annual programs and CRP.

The cotton base idled was down 0.4 million acres from the 3.1 million idled last year due to the smaller ARP. This occurred in spite of a larger acreage participating in the program in 1993. The rice program participation this year was identical to 1992, but 0.2 million more acres of rice base are idled due to the increased ARP.

In addition to the slight increase in land idled by annual programs, an additional 0.7 million base acres were bid into the CRP in 1993. The net base acreage idled by annual programs and the CRP in 1993 increased 1.1 million acres above last year. The total crop base idled is now at the second lowest level since the CRP began--43.2 million acres. Program compliance results next spring may change the 1993 idled acres data significantly.

All acreage enrolled in the CRP must remain idle for the full 10-year life of the CRP contract. Base acreage in the CRP is preserved and could be eligible for program participation at the end of the CRP contract. However, it could also remain idle without loss of base after expiration of the CRP contract under provisions of the 1990 Farm Act.

Idled Acreage Up in Six Regions; All Were Down in 1992

Acreage idled in Federal programs is up in 1993 in the Corn Belt, Lake States, Delta States, Appalachian, Northeast, and Southeast (table 4). Program-idled acreage decreased in the Northern Plains, Southern Plains, Mountain, and Pacific regions as it did in all the farm production regions between 1991 and 1992.

Corn acreage idled increased in all regions, primarily as a result of doubling the ARP requirement for 1993. However, enrolled base acreage was also up nearly 7 percent from the complying acreage last year. In 1993, the enrolled base acreage of each program crop equaled or exceeded the complying base acreage in 1992.

The wheat base idled in 1993 declined in all regions except the Northeast. As for corn, the principal factor causing the decline was the change in ARP requirement, zero in 1993 as compared to 5 percent last year. The approximately 5 million acres of wheat base idled this year (including that planted to minor oilseeds) are participating in the 0/92 program. About one-third of the idled wheat acres are in the Southern Plains.

The idled acreage of upland cotton decreased and of rice increased in most regions as expected in response to the changed ARP requirements for 1993.

Base Acreage Continues Down From 1985 Peak

Total base acreage of major program crops--wheat, feed grains, cotton, and rice--reached a peak for the last decade at 240.3 million acres in 1985 (table 5). However, since 1986 the CRP has cut the effective base acreage each year, down to 211.3 million acres in 1993.

Complying base acreage is the part of effective base acreage operated by producers who participate in annual commodity programs. Participation in annual crop programs varies for several reasons, including the attractiveness of program provisions and outlook for crop prices. The proportion of the effective base enrolled (signed up) in 1993 is 83.1 percent, up 4.3 percentage points from 1992 and higher than any year since 1988. However, it is still 4 percentage points below the 1987 peak (table 5).

The acreage enrolled in annual crop programs increased about 5 percent overall in 1993, based on the June enrollment report. The enrolled base acreage of each program crop equaled or exceeded 1992 levels. Only rice did not increase enrolled base acreage over the complying base acreage in 1992. The enrolled base of corn increased

Table 4--Cropland idled under Federal acreage reduction programs, by region

Region	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993 1/
					Million acres					
Northeast	0.1	0.2	0.5	0.9	0.9	0.7	0.7	0.6	0.5	0.6
Lake States	1.6	2.0	4.2	7.0	6.7	4.7	4.7	4.7	4.0	4.6
Corn Belt	2.9	3.8	8.5	15.3	13.9	8.8	9.0	8.2	7.3	9.3
Northern Plains	9.4	10.1	14.3	19.7	20.8	15.8	16.8	18.4	14.8	14.0
Appalachian	0.3	0.5	1.3	2.7	3.0	2.3	2.3	2.1	1.9	2.1
Southeast	0.5	0.7	1.3	3.0	3.2	3.0	3.0	2.9	2.8	2.9
Delta States	1.3	1.9	2.4	3.5	3.1	3.0	2.6	2.7	2.2	2.4
Southern Plains	5.7	5.9	8.3	11.7	12.0	10.0	9.8	11.0	9.0	8.9
Mountain	3.9	3.9	5.4	8.7	10.2	9.1	9.6	10.5	9.3	8.8
Pacific	1.3	1.6	2.2	3.5	3.8	3.2	3.1	3.6	3.1	2.8
United States 2/ 3/	27.0	30.7	48.1	76.2	77.7	60.8	61.6	64.5	54.9	56.4

1/ Preliminary. Annual program data based on June ASCS Program Enrollment Report compiled from farmer's sign-up in March and April. 2/ Includes the 48 conterminous States. Because of rounding, regional data may not sum to U.S. totals. 3/ Includes cropland idled by 0/92 and 50/92 programs from 1986 through 1992, except for about 0.5 million acres in 1991, 0.7 million acres in 1992, and 1.0 million acres in 1993 enrolled in 0/92 or 50/92 programs and planted to minor oilseeds. Also includes 2.0 million acres enrolled in the Conservation Reserve Program in 1986, 15.7 million acres enrolled in 1987, 24.5 million acres enrolled in 1988, 29.8 million acres enrolled in 1989, 33.9 million acres enrolled in 1990, 34.4 million acres enrolled in 1991, 35.4 million acres enrolled in 1992, and 36.5 million acres enrolled in 1993.

Table 5--Principal and program crops planted, total base acreage, and other Federal program acreage statistics and relationships

Item	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993 1/
	Million acres									
Principal crops planted	358.3	353.0	338.2	315.3	318.3	331.6	326.9	326.0	327.6	320.8
Program crops planted	215.4	216.9	204.3	185.4	182.8	196.0	195.8	191.5	197.1	189.0
Total base acreage of program crops	234.4	240.3	235.0	236.4	239.2	239.0	238.4	235.2	234.7	234.6
Base acres in CRP 2/			1.2	10.0	15.5	19.0	21.8	22.0	22.6	23.3
Effective base acreage 3/	234.4	240.3	233.8	226.4	223.7	220.0	216.6	213.2	212.1	211.3
Complying base acreage	128.6	162.8	192.9	197.2	187.8	168.0	166.6	169.0	167.1	175.6 4/
Annual program set-aside	27.0	30.7	46.1	60.5	53.3	30.9	27.7	30.1 5/	19.5 5/	19.9 5/
Complying base minus set-aside	101.6	132.1	146.8	136.7	134.5	137.1	138.9	138.9	147.6	155.7 4/
Complying base planted	88.0	116.1	135.5	131.6	125.0	123.1	132.1	127.4	134.7	143.5 4/
	Percent									
Effective base acreage as percentage of principal crops planted	65.4	68.1	69.1	71.8	70.3	66.3	66.3	65.4	64.7	65.9
Complying base acreage as percentage of effective base acreage	54.9	67.7	82.5	87.1	84.0	76.4	76.9	79.3	78.8	83.1 4/
Complying base acreage as percentage of program crops planted	59.7	75.1	94.4	106.4	102.7	85.7	85.1	88.3	84.8	92.9 4/
Complying base planted as percentage of program crops planted	40.9	53.5	66.3	71.0	68.4	62.8	67.5	66.5	68.3	75.9 4/

1/ Preliminary. 2/ Program began in 1986. 3/ Total base acreage of program crops less base acres in CRP.
4/ Based on enrolled base acres for 1993. 5/ Excludes land in 0/92 and 50/92 programs planted to minor oilseeds.

nearly 7 percent from the complying corn base last year. Similarly, sorghum increased nearly 3 percent; barley, more than 6 percent; oats, nearly 11 percent; wheat, 4 percent, and all cotton, over 3 percent.

The maximum acreage that program participants may plant on their complying base acreage is the complying base acreage minus that required to be idled (ARP requirement). Because not all program participants plant up to their maximum acreage, the complying base actually planted is less. Some producers use the 0/92 and 50/92 programs to idle additional acreage. Due to weather conditions in 1993 and the possibility of signing up for the 0/92 program much later than usual, participation may greatly exceed the original enrollment.

Total acreage of program crops planted includes the acreage planted by program participants as well as by nonparticipants. The proportion of program-crop acreage enrolled in Federal programs rose from 33 percent in 1982 to 71 percent in 1987 and declined from 1987 through 1989. From 1990 through 1992 about two-thirds of the acreage of all program crops was produced by participants in annual Federal programs. However, based on the enrollment in 1993, that proportion will increase to a new high of more than 75 percent.

Flex Acre Provisions Allow Considerable Shift From Corn to Soybeans

Under 1990 farm legislation, the definition of "maximum payment acreage" limits deficiency payments to program participants to 85 percent of the base acreage established for their program crop, less the acreage required to be idled by the ARP requirement. The 15 percent of base acres on which deficiency payments will not be made are called "normal flex acres" and are unrelated to the individual program ARP requirements. These normal flex acres can be planted to the original program crop, another program crop, or an approved flex crop. Base acreage, however, would be retained in the program crop if the land use was flexed to other crops.

In addition to normal flex acres, an additional 10 percent of program crop base acres could be used as "optional flex acres." If a crop other than the original program crop is produced on these acres, the optional flex acres are not eligible for deficiency payments. However, program crops and oilseeds grown on either normal or optional flex acres are eligible for price support loans. Any optionally flexed acres are also considered planted to the program crop, thereby protecting the base.

Planting flexibility on up to 25 percent of the base acreage provides some incentive for a wider selection of crops and increased crop rotation. However, some crops are specifically excluded from production on flexed acres. Excluded are fruits and vegetables, including potatoes, dry edible beans, lentils, and specified types of dry peas. Any other crops may be excluded by the Secretary of Agriculture.

Based on program crop enrollment in 1993, the calculated normal flex acres would total about 26.3 million (table 6). An additional 17.5 million acres could be optionally flexed. Program enrollment for 1993 shows about 9.8 million acres of gross flexed acreage of the potential 43.9 million acres. This would infer that a high proportion of normal flex acres would still be planted to the original program crop and that the optional flex acres provision would not be heavily used. After accounting for land shifted from one program crop to another, the net flex acres amount to about 7.1 million, of which 7.0 million were to be flexed to nonprogram crops (table 6).

Table 6--Use of crop base flex area by program crop, 1993 1/

1993 Use of flex area	Program crop base acreage flexed 2/							
	Corn	Sorghum	Barley	Oats	Wheat	Cotton	Rice	Total
	Thousand acres							
Flexed from other program crops	839	428	82	71	723	531	16	2,690
Flexed to other program crops	-415	-279	-311	-255	-1,322	-123	-67	-2,772
Flexed to nonprogram crops:								
Soybeans	-2,318	-275	-121	-84	-1,497	-142	-241	-4,678
Minor oilseeds	-72	-21	-105	-25	-366	-40	-41	-669
Other nonprogram crops	-232	-131	-190	-48	-976	-83	-29	-1,689
Subtotal - Nonprogram crops	-2,622	-427	-416	-157	-2,839	-265	-311	-7,036
Net change from flex provisions	-2,198	-278	-645	-341	-3,438	143	-362	-7,118
Normal flex acres 3/	-9,972	-1,646	-1,330	-487	-10,244	-2,044	-594	-26,317
Optional flex acres 4/	-6,648	-1,097	-887	-324	-6,829	-1,362	-396	-17,543
Total flex acres possible	-16,620	-2,743	-2,217	-811	-17,073	-3,406	-990	-43,860

1/ Preliminary . Based on the June ASCS Program Enrollment Report compiled from farmer's sign-up in March and April. 2/ A positive number indicates the area flexed into the crop heading the column from another program crop. A negative number indicates the area flexed (or available for flexing) out of the crop heading the column to another crop. 3/ Normal flex acres were computed as 15 percent of enrolled base acres of the program crops. 4/ Optional flex acres could be up to an additional two-thirds of the normal flex acres (10 percent of enrolled base acres).

The information in table 6 indicates the direction and magnitude of change in the program crop at the head of each column. That is, corn gained 839,000 acres flexed from other program crops. In turn, 415,000 acres were flexed out of corn and into other program crops. In total, including land flexed into nonprogram crops, corn lost nearly 2.2 million acres, of which the acreage flexed to soybeans was 119 percent of the net acreage flexed. More corn acres could be flexed to soybeans than were flexed out of corn in net terms, because a larger acreage was flexed into corn from other program crops than was flexed out of corn to other program crops.

Although there were shifts into and out of each program crop, only corn, sorghum, and cotton gained larger areas than they lost to other program crops through the flex provisions. On a relative basis, cotton gained considerably more than corn or sorghum and was the only program crop to have a net increase from the crop flex provisions. Cotton increased by 143,000 acres, net of land flexed from cotton to other crops. In contrast, even though corn gained more acres from other program crops than was flexed to other program crops, corn experienced a considerable acreage loss, primarily to soybeans. Soybeans gained nearly 4.7 million acres (66 percent) of the more than 7 million net flex acres from all program crops in 1993.

In comparing the gross acres (both normal and optional) flexed out of program crops to the potential normal flex acres, a smaller proportion of cotton acres were flexed (19 percent) followed by corn (31 percent). Oats experienced the greatest flex of acres to other crops--nearly 85 percent. The relatively small acreage shifts in crops through the acreage flex provisions infers that producers' preferred crop rotations have not been constrained by past base acreage provisions. The pattern of acreage flexing in 1993 is quite similar to 1991 and 1992. However, producers have an opportunity to change their acreage flex plans through the final program certification date. This year, the final certification date was moved to September 17 in designated disaster areas.

Corn, Sorghum, Barley, Oats, Soybeans, and Rice Acreage Down in 1993

Harvested acreage of corn, sorghum, barley, oats, soybeans, and rice is expected to decrease in 1993, while the acreage of wheat and cotton is estimated to increase from last year (table 7). Total harvested cropland is expected to be down nearly 9 million acres from a year earlier. The decrease in harvested acreage can be partly attributed to the increase in land idled in Federal programs. However, a larger part of the decrease is due to wet conditions at planting time and severe flooding in the Northern Plains, Lake States, and Corn Belt regions; to the drought conditions in the Southeast and Appalachian regions; and to killing frosts prior to crop maturity.

Harvested corn acreage in 1993 is forecast at 63.1 million, down 9 million from a year earlier. Largest decreases are predicted for the Corn Belt (-4.8 million acres), Lake States (-2.4 million), and Northern Plains (-1.2 million acres). The decrease in the Corn Belt follows large increases the last 2 years and the harvested acreage is estimated to be more than 3 percent below the 1987-91 average. The estimated acreage of corn harvested for grain also declined in the Appalachian, Southeast, and Delta States regions. Acreage gains were reported for the Southern Plains, Mountain, and Pacific regions.

Sorghum acres harvested for grain in 1993 are estimated at 9.7 million, down 2.5 million (20 percent) from a year earlier. However, the year-to-year drop is somewhat misleading because in 1992 more than 1 million acres of sorghum were planted on failed cotton acres in Texas. The sorghum acreage did decrease or was unchanged in all regions that normally produce sorghum. The 1993 estimate of harvested sorghum area is about 2 percent above the 1987-91 average.

The acreage of barley harvested is estimated to decrease 0.2 million acres (2.4 percent) from 1992. A decrease in barley acreage is indicated in the Northern Plains and the Pacific regions. All other regions are unchanged from

Table 7--Harvested area of major crops, by region

Crop	Period	North-east	Lake States	Corn Belt	Northern Plains	Appa-lachian	South-east	Delta States	Southern Plains	Mountain	Pacific	United States 1/
						Million acres						
Corn: 2/												
	1987-91 Ave.	2.2	10.2	32.2	11.6	3.1	1.2	0.4	1.5	1.0	0.3	63.7
	1992	2.4	11.8	35.9	13.5	3.4	1.5	0.7	1.8	1.0	0.2	72.1
	1993	2.2	9.4	31.1	12.3	3.0	1.2	0.6	2.0	1.1	0.3	63.1
Sorghum: 2/												
	1987-91 Ave.	-	-	0.7	5.0	0.1	0.1	0.6	3.0	0.4	3/	9.9
	1992	-	-	1.0	5.0	0.1	0.1	0.8	4.8	0.4	-	12.2
	1993	-	-	0.9	4.4	0.1	0.1	0.4	3.6	0.3	-	9.7
Barley:												
	1987-91 Ave.	0.2	0.9	-	3.3	0.1	3/	-	3/	2.8	1.0	8.4
	1992	0.2	0.8	-	3.1	0.1	3/	-	3/	2.3	0.8	7.3
	1993	0.2	0.8	-	3.0	0.1	3/	-	3/	2.3	0.7	7.1
Oats:												
	1987-91 Ave.	0.4	1.6	1.1	2.0	0.1	0.1	3/	0.3	0.2	0.1	6.0
	1992	0.3	1.2	0.8	1.6	0.1	0.1	3/	0.2	0.2	0.1	4.5
	1993	0.3	1.1	0.5	1.3	3/	0.1	3/	0.2	0.1	0.1	3.8
Wheat:												
	1987-91 Ave.	0.6	3.2	4.9	25.1	1.6	1.1	1.8	8.7	9.1	3.6	59.7
	1992	0.6	3.5	4.1	27.7	1.5	0.7	1.3	9.7	9.3	4.0	62.4
	1993	0.5	3.0	4.7	27.8	1.6	0.7	1.3	9.1	10.0	4.2	63.0
Soybeans:												
	1987-91 Ave.	1.1	6.5	29.6	6.8	4.2	2.2	7.0	0.5	-	-	57.7
	1992	1.2	7.5	30.0	7.2	4.0	1.6	6.1	0.6	-	-	58.2
	1993	1.2	7.0	29.2	6.3	3.8	1.4	6.6	0.5	-	-	56.0
Cotton:												
	1987-91 Ave.	-	-	0.2	3/	0.7	0.9	2.5	5.2	0.5	1.1	11.2
	1992	-	-	0.3	3/	1.0	1.1	3.2	3.9	0.5	1.1	11.1
	1993	-	-	0.3	3/	1.0	1.2	3.2	5.9	0.4	1.1	13.3
Rice:												
	1987-91 Ave.	-	-	3/	-	-	-	1.9	0.3	-	0.4	2.7
	1992	-	-	0.1	-	-	-	2.3	0.4	-	0.4	3.1
	1993	-	-	0.1	-	-	-	2.1	0.3	-	0.4	2.9

- = None reported.
1/ Includes the 48 conterminous States. Because of rounding, regional acres may not sum to U.S. totals. 2/ Corn and sorghum for grain. 3/ Less than 50,000 acres.

1992. The 1993 harvested acreage of barley is more than 15 percent below the 1987-91 average.

Harvested oats acreage is estimated to be down 0.7 million acres from 1992 at 3.8 million acres. The largest decreases are in the Northern Plains and Corn Belt, but decreases are also indicated in the Lake States, Mountain, and Appalachian regions.

Wheat acreage harvested in 1993 is estimated at 63.0 million acres, up 0.6 million from a year ago and 3.3 million acres above the 1987-91 average. Although an increase, the change represents only 25 percent of the 2.4 million fewer wheat base acres idled in 1993 than in 1992. This pattern is quite similar to the 1991-92 change due to low prices and dry conditions at winter wheat planting time, as well as the first experience with the crop flex provisions for many winter wheat producers, but those reasons do not fit well this year. One possible reason for the small increase this year relative to the decrease in base acreage idled is the higher wheat base flexed to other crops in 1993.

The largest increases in wheat acreage harvested were in the Mountain and Corn Belt regions. These were followed by successively smaller increases in the Pacific, Northern Plains, and Appalachian regions. Decreases in wheat acreage occurred in the Southern Plains, Lake States, and Northeast, while the Southeast and Delta States was unchanged from last year. As indicated earlier, a large area of wheat base was idled in the Southern Plains, in spite of the zero ARP requirement, through participation in the 0/92 program.

Soybeans are expected to be harvested on 56.0 million acres in 1993, about 2.2 million fewer than in 1992. This harvested acreage is the lowest of recent history and resulted primarily from the wet conditions at planting time in several regions of the country; drought conditions in the Southeast and Appalachian regions; and early killing frosts in portions of the principal growing areas. Estimated soybean acreage harvested increased only in the Delta States.

The cotton acreage harvested is estimated at 13.3 million in 1993, up 2.2 million from 1992. Land idled in the 1992 annual cotton program decreased by 0.4 million acres from the 1992 crop year, primarily as a result of the reduced ARP requirement. The increase in cotton acreage is largest in the Southern Plains (2.0 million acres) followed by a small increase forecast for the Southeast. Estimated cotton acreage harvested decreased in the Mountain region and was unchanged in the other five farm production regions that normally produce cotton.

Rice acreage harvested in 1993 is expected to be down to about 2.9 million acres. This acreage, however, is more than 7 percent above the 1987-91 average area harvested. The reduced acreage from 1992 occurred in the Delta States and Southern Plains. There was no change from last year in the Corn Belt or Pacific regions.

Fertilizer Use and Prices Expected Up in 1994

Planted acres in 1994 are expected to increase over 1993 (especially corn) since a zero ARP for 1994 wheat was set in July and a 5 percent ARP for 1994 corn was set September 30.

Enduring political and economic restructuring in Eastern Europe, the former USSR, China, India, and the Middle East will likely reduce 1992/93 world fertilizer production and consumption compared to 1991/92. The disintegration of their command economies and slow evolution toward open markets has created a hard currency shortage and fertilizer production and distribution problems for former USSR and East European countries. Demand for fertilizer is down since prices are no longer subsidized or subsidized at a much lower rate than earlier, and relative prices of agricultural products are down sharply. As a result, fertilizer consumption in these areas is down. Closing non-economic plants and reducing investment in new plants could result from this reduced effective demand.

Fertilizer supplies in the United States during 1994 are expected to be ample at stable to slightly higher prices. However, planted acreage of the major fertilizer-using crops will be the main factor determining 1994 usage. Available fertilizer supplies, world demand, and petroleum (especially natural gas) and sulphur prices are significant influences on fertilizer prices.

Largely because of the Midwest floods, 1993 planted acreage was revised down in July and August. For example, in September planted acreage of all corn was estimated at 73.7 million acres, down 0.6 million from the June acreage report and 7 percent from 1992. The lower than anticipated 1993 crop and resulting drawdown in stocks led to the Secretary of Agriculture announcing a 5 percent 1994 acreage reduction program (ARP) for corn (10 percent last year). In July, a 0 percent ARP for wheat (the same as last year) was announced. In addition, 1994 ARP's for barley, sorghum, and oats were set at 0 percent. As a result, fertilizer usage should increase, as corn is the largest user of fertilizer.

Consumption

U.S. plant nutrient use is estimated to have decreased to 19.8 million tons during the 1992/93 fertilizer year (July 1-June 30), down 4.1 percent from 20.7 million tons a year earlier. After the effects of the Midwest flood have been more fully analyzed, 1992/93 estimates may be even lower. Most of the decrease was due to less corn planting. Corn acreage, which accounted for an estimated 44 percent of plant nutrient use in 1991/92, fell 7 percent; wheat acreage, with 14 percent of nutrient use, remained about the same as a year earlier (table 8).

The April 1993 index of prices paid by farmers for all fertilizers was 2 percent less than spring 1992. Domestic and international supplies exceeded world consumption, resulting in lower fertilizer prices.

Fertilizer Use on Winter Wheat

Fertilizer was applied to 87 percent of the winter wheat acres harvested in 1993 (table 9), 3 percent more than the previous year. The proportion of winter wheat acres treated with nitrogen, phosphate, and potash increased to 86, 49, and 15 percent. Nitrogen per-acre application rate decreased from 66 to 63 pounds. The application rate for phosphate remained the same at 37, but potash increased to 15 pounds. Idaho acreage received the most nitrogen per acre at 102 pounds, while Illinois and Ohio had the highest application rates for phosphate and potash at 70 and 66 pounds per acre, respectively. The least amount of nitrogen per acre (36 pounds) was applied in South Dakota.

Fertilizer Use on 1992 Fall Potatoes

Some fertilizer was applied to over 99 percent of the acreage planted to fall potatoes in 1992; the proportion of acres treated ranged from over 99 percent for nitrogen to 88 percent for potash (table 10). The area average for nitrogen was 200 pounds per acre, while that for phosphate was 159 pounds, and 147 pounds for potash.

Application rates for the three nutrients varied significantly by State. Similar to last year, North Dakota acreage received the least amount of nitrogen and phosphate, and North Dakota and Colorado acreage had the least amount of potash. Washington received the highest per acre applications of nitrogen and phosphate and Wisconsin the most potash.

Table 8--Planted crop acreage, U.S.

Crop	1992	1993	Change
	Million acres		Percent
Wheat	72.3	72.1	-0
Feed grains	108.4	100.4	-7
Corn	79.3	73.7	-7
Other 1/	29.0	26.6	-8
Soybeans	59.3	59.5	0
Cotton	13.2	13.7	4
Rice	3.2	3.0	-5

1/ Sorghum, barley, and oats.

Table 9--Fertilizer use on winter wheat, 1993 1/

State	Acres 2/	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P2O5	Acres receiving: K2O	Application rates: N	Application rates: P2O5	Application rates: K2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	Thousand	No.	Percent				Pounds per acre			Percent		
Colorado	2,550	78	67	67	14	4	50	41 **	22 **	75	19	6
Idaho	850	93	95	95	62	8	102	37	19 **	40	22	38
Illinois	1,550	75	99	99	81	68	87	70	83	13	19	68
Kansas	11,300	252	87	87	51	8	55	30	19 *	62	10	28
Missouri	1,400	67	98	96	77	75	84	52	61	34	22	44
Montana	2,500	93	88	88	84	12	41	29	17 **	79	2	19
Nebraska	2,100	100	80	75	39	12	48	24	10 *	68	13	20
Ohio	1,000	70	99	99	95	95	79	66	74	12	5	84
Oklahoma	5,500	153	96	96	50	10	68	38	22 *	54	11	35
Oregon	860	86	97	93	13	8	62	36 **	31 **	59	12	29
South Dakota	1,400	64	45	45	36	2	36 *	29	9	56	18	25
Texas	3,700	183	77	77	32	5	79	40	16 *	60	19	21
Washington	2,501	139	98	98	38	5	65	22	23 **	81	4	14
Area:												
1993	37,211	1,453	87	86	49	15	63	37	48	58	12	30
1992	36,990	1,592	85	85	46	13	66	37	40	57	12	31
1991	34,180	1,655	84	84	49	19	65	40	54	58	12	30

* - CV greater than 10 percent. ** - CV greater than 20 percent.
1/ Preliminary. 2/ Acres harvested for winter wheat.

Table 10--Fertilizer use on fall potatoes, 1992

State	Acres planted 1/	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P2O5	Acres receiving: K2O	Application rates: N	Application rates: P2O5	Application rates: K2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000	No.	Percent				Pounds per acre			Percent		
Colorado	67	48	100	100	98	79	190	183	77	2	0	98
Idaho	380	299	99	99	99	80	234	173	98	15	6	79
Maine	81	160	100	100	99	99	168	179	179	80	3	17
Michigan	37	75	100	100	100	95	214	161 *	219	24	0	76
Minnesota	71	94	99	99	97	96	116	81	117	71	0	29
New York 2/	21	48	100	100	100	100	131	178	235	75	2	23
North Dakota	145	93	100	99	97	87	90	66	76 *	78	0	22
Oregon	45	144	99	99	98	88	185	158	159	24	4	71
Pennsylvania	20	85	100	100	100	98	149	120	134	76	0	24
Washington	125	172	100	100	99	98	308	246	246	39	15	47
Wisconsin	66	141	100	100	99	98	222	144	301	11	2	87
Area:												
1992	1,058	1,359	100	100	99	88	200	159	147	37	4	58
1991	1,116	1,396	99	99	98	88	195	158	143	37	3	60
1990	1,087	1,157	99	98	98	89	198	163	143	41	4	54

* - CV greater than 10 percent.
1/ Preliminary. 2/ Does not include Long Island.

Use of Manure, Lime, Sulfur, and Micronutrients in 1992

Manure was applied to 16 percent (19 percent in 1991) of all corn acres surveyed in 1992 (table 11). Use ranged from 43 percent (same as in 1991) of corn acres in Wisconsin to 7 percent in Missouri and Nebraska. Manure use on other crop acreage was less common, ranging from 6 percent for soybeans to 2 percent for winter wheat. Micronutrient use also varied considerably by crop; over half of the potato acres planted received micronutrients in 1992, while only 2 percent of wheat acres were treated.

Lime is applied to balance a soil's pH (a measure of its acidity or alkalinity), which increases the yield potential of crops by improving the availability of soil nutrients. The frequency of lime applications can range from every year on highly acidic soils to every 5-10 years on the less acidic soils in the Midwest. Lime was applied to 4 percent of the corn acres surveyed in 1992, but no lime was reported used on rice or durum wheat. Lime application rates ranged from 1.9 tons per acre for corn to 0.1 tons for spring wheat.

Like other essential nutrients, sulfur plays an important role in plant growth. Plants low in sulfur are often small and spindly, and sulfur deficiency can cause reduced root nodulation in legumes. Sulfur use was more common than lime on all crops surveyed except soybeans. Sulfur use

Table 11--Manure, lime, sulfur, and micronutrient use on selected crops, 1992

Crop	Acres 1/	Acres receiving: Manure	Acres receiving: Lime	Acres receiving: Sulfur	Acres receiving: Micro-nutrients	Application per acre: Lime	Application per acre: Sulfur
	1,000	Percent				Tons	Pounds
Corn	62,850	16	4	11	11	1.9	11
Cotton	10,200	3	1	22	18	1.4	13
Potatoes	1,063	3	6	57	57	0.9	61
Rice	1,950	3	NR	10	9	NR	18
Soybeans	48,630	6	5	1	2	1.6	10
Wheat:							
All	56,540	3	1	0	2	1.4	13
Durum	2,200	4	NR	2	NR	NR	1
Spring	17,350	4	*	3	1	0.1	10
Winter	36,990	2	2	12	2	1.5	14

nr - None reported. * - Less than 0.5 percent.
1/ Includes the major producing States for each crop. Information is based on harvested acres for winter wheat and planted acres for all other crops.

was most prevalent on fall potatoes; calcium sulfate is frequently applied to extend potato storage life. Of the potato acres surveyed, 57 percent received an average of 61 pounds of sulfur per acre in 1992.

Futures Market

Since its inception, fertilizer future contract trading has been weak. In an effort to strengthen the market, the Chicago Board of Trade (CBOT) voted August 17, 1993, to amend diammonium phosphate (DAP)--18-46-0 and anhydrous ammonia regulations by increasing the deliverable supplies of product and changing trading hours. The new times are an hour earlier than before and are meant to allow fertilizer trading to open before other agricultural markets. The new trading hours are 8:00 a.m. to 12:15 p.m. for DAP and 8:05 a.m. to 12:20 p.m. for anhydrous ammonia. CBOT also approved applications for several shippers to increase deliveries. The increases would raise the deliverable supply of DAP by 10 percent from 1,990 shipping certificates to 2,190. The change would allow on-water Florida shippers to handle rail loadings and would be effective for September 1994 contracts. The Board also approved a proposal to increase the deliverable supply of anhydrous ammonia by 17 percent, from 1,087 to 1,277 shipping certificates.

Supplies

Effective January 1990, the U.S. Department of Commerce (DOC) reinstated the reporting of anhydrous ammonia quantity data for all countries except imports from the former USSR. Since imports from the former USSR represent a large portion of U.S. imports, nitrogen imports and domestic supply are significantly understated in this report.

Domestic supplies of nitrogen and phosphate in 1992/93 increased from a year earlier while potash supplies went down. Supplies increased for nitrogen and phosphate even though production was down because of higher inventories and increased imports (table 12). Domestic supplies of potash decreased due to reduced production and lower imports.

Table 12--U.S. fertilizer supplies 1/

Item	1991/92	1992/93	Change
	Million short tons		Percent
July 1 inventory:			
Nitrogen	1.01	1.14	13
Phosphate 2/	.57	.54	-5
Potash	.19	.25	32
Production:			
Nitrogen	14.62	14.18	-3
Phosphate 2/	12.51	12.31	-2
Potash	1.92	1.72	-10
Imports:			
Nitrogen	3/ 3.59	3/ 3.89	8
Phosphate 2/	.07	.18	157
Potash	5.24	4.80	-8
Exports:			
Nitrogen	3/ 3.42	3/ 2.54	-26
Phosphate 2/	5.58	5.19	-7
Potash	.66	.52	-21
Domestic supply: 4/			
Nitrogen	3/ 15.80	3/ 16.67	6
Phosphate 2/	7.57	7.84	4
Potash	6.69	6.25	-7

1/ Data for July through June for the fertilizer year starting July 1. 2/ Does not include phosphate rock. 3/ Does not include imports of anhydrous ammonia from the former USSR. Thus, nitrogen imports and domestic supply are significantly understated. 4/ Includes requirements for industrial uses.

Trade

Depressed world demand for fertilizer and reduced U.S planted acres caused U.S. production and exports to decline during 1992/93 when compared to the year earlier.

U.S. nitrogen, phosphate, and potash exports (nutrient content) during July 1992-June 1993 decreased 26, 21, and 22 percent, respectively from last year. Urea exports to Canada, and China went down 71 and 61 percent, respectively, while diammonium phosphate (DAP) exports to India and China decreased 47 and 51 percent. Exports of monoam-

monium phosphate (MAP) to Canada and potash to Brazil increased 7 and decreased 41 percent, respectively.

The volume of fertilizers exported from the United States varied when compared with the year earlier. For July 1992-June 1993, DAP exports fell 26 percent from 10.7 to 7.9 million tons while monoammonium phosphate exports went down 7 percent from 1.12 to 1.04 million tons. Phosphate rock exports continued declining to 3.9 million tons, a 30 percent decrease. The phosphate rock of other exporting countries has a higher ore content than that of the United States.

Nitrogen solution exports decreased 50 percent from 395,000 tons in 1991/92 to 196,000 in 1992/93. Urea exports decreased 35 percent from 1.16 to 0.76 million tons, and concentrated superphosphate exports decreased 6 percent to 1.1 million tons. Exports of ammonium nitrate and ammonium sulfate went up 34 and 3 percent, while potassium sulfate and potassium chloride decreased 2 and 29 percent, respectively.

The main fertilizer deficit areas will continue to be in Asia, particularly China and India. In addition, France, Belgium, Italy, Japan, Pakistan, Korea, Mexico, and Brazil continue to be major recipients of U.S. fertilizer. During July 1992-June 1993, over 32 percent of urea exports and 33 percent of diammonium phosphate exports-- representing 245,000 and 2.6 million tons of product, respectively-- went to China. India received about 13 percent of DAP exports, while South Korea and Chile obtained another 25 and 10 percent of urea, respectively.

Canada, Belgium-Luxembourg, and France remain important buyers of U.S. nitrogen solutions, receiving 66,000, 59,000, and 32,000 tons (80 percent) of these exports during 1991/92. Brazil and Mexico received 395,000 and 172,000 tons or 44 and 19 percent of ammonium sulfate exports, respectively. Brazil also received 210,000 tons or 38 percent of potassium muriate exports. Australia, Brazil, Indonesia, and Chile received 283,000, 174,000,159,000 and 155,000 tons or 26, 16, 15, and 14 percent of concentrated superphosphate exports. Phosphate rock exports have declined as a result of increased competition from Morocco. South Korea, Canada, Japan, the Netherlands, Belgium-Luxembourg, Germany, and India remained the major recipients.

Fertilizer material imports for many products were less than year-earlier levels. Potassium chloride imports during July-June were down 9 percent from a year earlier to 7.7 million tons. Imports of potassium chloride from Canada remained strong at around 92 percent of the total, and those from Russia, and Israel decreased to 3 and 2 percent of the total. Ammonium nitrate imports were up 3 percent to 520,000 tons, and ammonium sulfate imports went down 4 percent to 364,000 tons. Anhydrous ammonia imports were down 8 percent. However, urea imports increased 57 percent from 1.7 to 2.6 million tons, with imports from Canada responsible for 38 percent of the total.

Production

Domestic nitrogen, phosphate, and potash fertilizer production decreased during 1992/93 in response to less domestic planted acres and reduced world consumption. The slow evolution of the former USSR and Eastern Europe toward a market economy has caused reduced world demand. In response, U.S. nitrogen production decreased 3 percent during July 1992-June 1993; however some anhydrous ammonia producers operated at close to capacity. Phosphate production decreased 2 percent and U.S. potash production was down 10 percent from a year earlier.

Prices

Aggregate farm fertilizer prices in spring 1993 were 2 percent less than a year earlier (table 13). Reduced world demand as a direct result of the economic reforms in Eastern Europe, the former USSR, China, India, and the Middle East, and excess U.S. production pushed prices down. In addition, planted U.S. acres in 1993 were less than anticipated by the fertilizer industry, resulting in excess domestic supplies and lower fertilizer prices.

Nitrogen prices generally have changed less than phosphate or potash prices since spring 1992, with anhydrous ammonia price increasing 2 percent. Prices of other nitrogen materials either remained constant or changed slightly. Triple superphosphate and diammonium phosphate prices went down 8 and 11 percent. Potash prices also decreased slightly; the price of potassium chloride went from $150 to $146 per ton in April from year earlier levels.

Prices paid by farmers for fertilizer products reflect wholesale trends as well as other economic relationships. Since spring 1993, fertilizer wholesale prices have dropped in response to excess domestic supplies and reduced demand. This seasonal down-turn in prices will likely reverse direction later this fall, as dealers increase stocks in anticipation of demand next year. Fall retail prices are typically less than the following spring prices. Spring 1994 prices will likely be higher than fall 1993 prices, reflecting expectations for increased 1994 planted acreage of fertilizer intensive crops such as corn, and higher fertilizer production costs.

Table 13--April farm fertilizer prices 1/

Year	Anhydrous ammonia (82%)	Phosphates: triple super- (44-46%)	Phosphates: diammonium (DAP) (18-46-0%)	Potash (60%)	Mixed (6-24-24%)	Prices paid index 1977=100
	Dollars per short ton					
1987	187	194	220	115	176	117
1988	208	222	251	157	208	132
1989	224	229	256	163	217	141
1990	199	201	219	155	198	130
1991	210	217	235	156	206	136
1992	208	206	224	150	200	132
1993	213	190	199	146	190	129

1/ Derived from the April survey of farm supply dealers conducted by NASS, USDA.

Continued Slow Growth in Conservation Tillage for Winter Wheat and Potatoes

To meet conservation compliance requirements, potato producers are expected to rely on crop rotations and cover crops instead of tillage systems. Winter wheat producers are often in compliance with their current tillage operations.

Tillage operations and amount of previous crop residue on the soil surface after planting are important indicators of soil erosion potential. The conservation compliance provisions of the 1985 Food Security Act and the Food, Agriculture, Conservation, and Trade Act of 1990 require farmers to implement conservation practices on highly erodible land (HEL) by 1995 to be eligible for most USDA program benefits. Recommended practices to meet these requirements include a change in crop rotation, different tillage system, additional cropping practices (such as contouring), and/or installation of permanent structures. The United States Department of Agriculture (USDA) has developed soil conservation plans for 141 million acres of highly erodible U. S. cropland. These plans include crop residue management as part of the recommended treatment on about 75 percent of the 110 million HEL acres planted to crops.

For water erosion control purposes, a conservation tillage system is defined as one that leaves 30 percent or more of the soil surface covered with previous crop residue after planting. Conservation tillage systems include mulch-till, no-till, and ridge-till. Conventional tillage methods (with and without the moldboard plow) leave less than 30 percent. Since the various tillage systems leave significantly different residue levels, the type of system directly affects erosion potential and water quality. In general, conventional tillage systems without the moldboard plow leave less than one-half as much residue after planting as mulch-till systems. High residue tillage systems, such as no-till and ridge tillage, can leave as much as 70 percent coverage of the soil surface and offer more protection against erosion.

Tillage system designations for the Economic Research Service Cropping Practices Survey were based on the use or nonuse of specific tillage implements and estimates of residue remaining after planting (1).

Winter Wheat

A steady decline in the use of the moldboard plow has been reported in winter wheat production since 1988 (table 14). A corresponding increase has occurred in conventional tillage without the plow and in no-till. No large increase in conservation tillage acreage is expected for next year as conservation compliance plans are implemented.

Over one-third of the 1993 winter wheat was harvested from HEL (appendix table 1). On HEL designated fields, 75 percent use conventional tillage, 3 percent with the moldboard plow and 72 percent without.

Conventional tillage on HEL land may create the potential for significant erosion. However, HEL acres which are conventionally tilled should not be interpreted as the acreage that would be out of compliance with the 1985 and 1990 farm bills. If conditions are favorable and the fall-planted winter wheat gets a reasonable start, growing wheat probably provides enough cover to meet the erosion rate restrictions during critical erosion periods. This is particularly true for the spring wind erosion period in most western States. These acres might meet compliance requirements no matter which tillage system was used.

Other factors influence erosion rates and would also directly relate to meeting conservation compliance requirements. Soil-loss equations consider the entire length of a rotation, not just the current crop and its tillage system, in the calculation of erosion rate. The calculated rate is the average of the sum of the individual rates of each crop, tillage, and practice combination over the life of the rotation. In addition, the presence of other practices, such as contouring or terracing, would reduce the erosion rate. The soil and its erodability characteristics also have a large influence, as does the weather. These items are also considered in soil-loss equations.

In the western States, wind erosion is usually more of a problem than water erosion. A greater proportion of total acreage may be affected because wind erosion is not limited to the more sloping soils. Many western winter wheat producers follow a wheat-fallow rotation. They usually begin the fallow period by roughening the soil by chisel or sweep plowing, leaving residue on the soil surface. This not only decreases wind erosion but helps capture moisture. Winter wheat is planted the following fall and plant growth provides protection during the next spring's critical wind erosion period.

On the other hand, acres producing winter wheat with conservation tillage might not automatically be in compliance. If the previous crop leaves little residue or any tillage operations leave bare soil during critical erosion periods, even conservation tillage acreage may have erosion rates above compliance limits.

Oregon reported the heaviest reliance on the moldboard plow (36 percent) among major States harvesting winter

Table 14--Tillage systems used in winter wheat production, 1988 - 1993 1/

Category	1988	1989	1990	1991	1992	1993
Harvested acres (1,000) 2/	32,830	34,710	40,200	34,180	36,990	37,210
	Percent of acres 3/					
Tillage system:						
Conv/w mbd plow 4/	15	16	12	12	11	7
Conv/wo mbd plow 5/	67	68	69	72	68	76
Mulch-till 6/	16	15	17	13	18	14
No-till 7/	1	1	3	3	3	4
Residue remaining after planting:	Percent of soil surface covered					
Conv/w mbd plow	2	2	2	2	2	2
Conv/wo mbd plow	14	14	14	14	14	13
Mulch-till	38	35	38	38	38	39
No-till	61	66	53	57	58	54
Average	17	17	18	17	19	18
	Number					
Hours per acre:						
Conv/w mbd plow	.7	.7	.7	.7	.6	.7
Conv/wo mbd plow	.5	.5	.5	.5	.5	.5
Mulch-till	.4	.4	.3	.4	.4	.3
No-till	.1	.1	.1	.1	.1	.1
Average	.5	.5	.5	.5	.5	.4
Times over field:						
Conv/w mbd plow	5.3	5.3	5.3	5.6	5.3	5.6
Conv/wo mbd plow	5.0	4.8	5.0	5.0	4.9	5.0
Mulch-till	4.5	4.1	4.0	4.2	4.2	4.1
No-till	1.0	1.0	1.0	1.0	1.0	1.0
Average	4.9	4.7	4.7	4.9	4.7	4.7

1/ Arkansas and Indiana not included in 1993. 2/ Preliminary. 3/ May not add to 100 due to rounding. 4/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 5/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 6/ Mulch-tillage--a system that has 30 percent or greater remaining residue after planting and is not a no-till system. 7/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

wheat in 1993 (appendix table 1). According to Extension personnel, some western producers believe that the risk of disease is intensified when large amounts of wheat residue are left on the soil surface. Many of these States follow a wheat-fallow or a wheat-wheat-fallow rotation. Colorado, South Dakota, and Oregon reported that mulch tillage was used on nearly 25 percent of winter wheat acreage. Illinois, Missouri, and Ohio reported over 20 percent no-till on winter wheat acreage. These States often plant winter wheat after fragile-residue soybeans. For example, in 1991 Missouri reported that 47 percent of the harvested winter wheat acreage was planted after soybeans, Illinois 67 percent, and Ohio 85 percent (2).

Illinois, Missouri, and South Dakota had the highest estimated residue remaining after planting (over 25 percent) because of extensive use of mulch-till and no-till methods. Oklahoma and Oregon had the lowest (13 and 14 percent) because of greater use of conventional tillage methods.

Except for the no-till system, wheat acreage normally has more trips over the field than most other field crops. This is because much of the wheat produced in the Great Plains and western States is produced after a fallow period (2). All implement trips over the field made during the fallow year were included in determining residue levels. The typical fallow procedure starts in the fall with chisel plowing and other noninversion tillage operations, instead of a single pass with the moldboard plow. For these States, therefore, more trips over the field may occur with conventional tillage without the moldboard plow than with the plow.

Potatoes

Conservation tillage systems are not common among potato growers (table 15). Growers normally hill the potatoes by cultivating and mounding dirt onto the rows. This process is made more difficult when large amounts of residue are present. Disease can also be a problem when residue is left. In rotations emphasizing potatoes, decaying vines or tubers may harbor the organisms for early or late

Table 15--Tillage systems used in fall potato production, 1989 - 1992

Category	1989	1990	1991	1992
Planted acres (1,000) 1/	1,011	1,087	1,116	10,200
	Percent of acres 2/			
Tillage system:				
Conv/w mbd plow 3/	39	35	34	35
Conv/wo mbd plow 4/	54	56	56	56
Mulch-till 5/	6	8	9	8
No-till 6/	id	id	id	1
Residue remaining after planting:	Percent of soil surface covered			
Conv/w mbd plow	2	2	2	2
Conv/wo mbd plow	10	11	12	10
Mulch-till	39	41	39	40
No-till	id	id	id	47
Average	9	10	11	10
	Number			
Hours per acre:				
Conv/w mbd plow	.9	1.0	.9	.8
Conv/wo mbd plow	.8	.7	.8	.7
Mulch-till	.5	.4	.5	.4
No-till	id	id	id	.2
Average	.8	.8	.8	.7
Times over field:				
Conv/w mbd plow	4.1	4.1	4.0	3.8
Conv/wo mbd plow	4.5	4.4	4.5	4.3
Mulch-till	2.9	2.8	3.0	2.7
No-till	id	id	id	1.0
Average	4.3	4.2	4.2	4.0

id - Insufficient data.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--no residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

blight. Rotations in irrigated areas usually include higher profit crops like corn in order to recapture fixed investments in irrigation equipment. Leaving corn residue can create the problem of corn roots interfering with hilling operations.

Wind erosion is a common problem on the flat, loamy-sandy soils used for potato production. Therefore, many of these soils are designated highly erodible. Cover crops, such as rye, are often used as erosion protection in the eastern States where fall moisture is usually not a limitation. This may partially explain why in some eastern States the moldboard plow is used more extensively (appendix table 2). In 1992, Pennsylvania farmers used the moldboard plow on 96 percent of fall potato acreage and New York and Wisconsin used the plow on over 65 percent.

In other States, producers used the moldboard plow less and retained more crop residue (particularly small grains) in order to comply with erosion reduction objectives and conserve moisture. From 10 to 21 percent mulch-till was reported in Maine, Minnesota, North Dakota, Washington, and Wisconsin.

The most feasible practices for potato growers to meet compliance restrictions may be the use of cover crops and the choice of rotations that generate residue containing no blight hazard. Production in 1993 and 1994 may show more changes in this direction.

In many States, total remaining residue averaged less than 10 percent. Overall, there was an average of more than four tillage passes on 1992 fall potato acreage.

References

1. Bull, Len. "Residue and Tillage Systems for Field Crops." Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Staff Report No. AGES 9310, July 1993.

2. U.S. Department of Agriculture, Economic Research Service. *Agricultural Resources: Situation and Outlook Report*, AR-28, October 1992, pp 7-12.

Small Changes Foreseen for Energy Prices and Consumption

The price of energy to farmers is expected to change little for the remainder of 1993 and for 1994 while energy consumption will fall slightly below that of recent years.

U.S. farmers can expect energy prices for the rest of 1993 and for 1994 to be at, or modestly above, their 1992 averages due to no or, at most, a small expected increase in the price for imported crude oil. For 1993, direct energy expenditures (about 3.8 percent of total cash farm production expenses) are expected to be 3 to 4 percent below the preceding year. The reduction is attributed to steady or minimally higher energy prices coupled with a slight decline in energy use associated with the Midwest flooding.

The World Crude Oil Price

The world crude oil price is affected by supply, demand, and other factors such as expectations of market participants. Each factor is subject to considerable uncertainty. For example, current uncertainties concerning oil supply involve oil exports from the former USSR and production from the Organization of Petroleum Exporting Countries (OPEC).

In the former USSR, the production and domestic consumption of crude oil are expected to decline. The volume of crude oil available for export will be determined by the rate of decline in consumption relative to production as well as by the need for foreign exchange in the emerging market economies of the new republics.

Two OPEC countries, Kuwait and Iraq, are in the process of restoring their pre-war production capacity and export facilities. Kuwait is expected to increase oil production and exports as capacity is restored, although production may be held below capacity in compliance with OPEC production quotas. Iraqi production will be constrained as long as the United Nations embargo against exports remains in effect. Aggregate OPEC production depends on the willingness of other OPEC members to increase their production, if necessary, as exports from Kuwait, and possibly Iraq, remain below normal.

The important uncertainties affecting oil demand over the next year or so include the magnitude of economic growth in the United States, Japan, and Western Europe and the severity of winter weather. Steady economic recovery is expected in Organization for Economic Cooperation and Development (OECD) countries. In the short run, variations in weather could have a greater impact on demand than variations in economic activity.

Two other uncertainties affect the extent to which these supply and demand uncertainties influence crude oil prices: excess crude oil production capacity and stocks of crude. Excess capacity is expected to increase by 1.6 million barrels in the remainder of 1993 and in 1994 as increases in OPEC production will be somewhat less than additions to production capacity. During the last half of 1993 and the first quarter of 1994, the market economies are expected to have enough stocks readily available to meet petroleum demand for over 30 days, based on anticipated demand. This is about 3 days more than the same period in 1992 and 1993.

Given these uncertainties, the world price of crude oil is forecast by the Department of Energy to remain approximately unchanged through the end of 1993 and increase slightly in 1994.

Domestic Petroleum Consumption and Production

The Department of Energy has analyzed the consumption and production of refined petroleum products in the United States, assuming an average world price of crude oil of $18.77 per barrel through 1994. With a modestly higher world crude oil price and a sluggish, though rebounding, economy, U.S. petroleum demand is expected to increase. At a world price of $18.77 per barrel, the demand for all refined petroleum products in 1994 is expected to be 17.89 million barrels per day, a 2.5-percent increase from 1993 (table 16).

On the supply side, the $18.77-per-barrel price will not reverse the rate of decline in domestic crude oil production in 1994. As a result of this, coupled with increased domestic consumption, net crude oil and refined petroleum product imports are expected to increase 5.9 percent in 1994.

In the event of a $18.77-per-barrel world oil price, the U.S. price of crude oil is assumed to increase by $0.57 per barrel (1.4 cents per gallon) from the fourth quarter of 1992 to the fourth quarter of 1994. Most refined petroleum product prices would see little change, although there are a couple of exceptions. Gasoline prices are expected to go up an additional 1 to 2 cents per gallon due to State and local tax increases following the 4.3 cents per gallon rise on October 1, 1993, in the federal excise tax on motor fuels that was part of the Administration's deficit reduction package.

The diesel fuel price will rise by 2 to 7 cents per gallon beginning in late 1993, due to federally mandated lower sulfur-content requirements. This is in addition to the 4.3 cents per gallon rise that occurred on October 1, 1993.

Table 16--U.S. petroleum consumption-supply balance

Item	1990	1991	1992	Forecast 1993	1994
	Million barrels/day				
Consumption:					
Motor gasoline	7.23	7.19	7.27	7.43	7.53
Distillate fuel	3.02	2.92	2.98	3.13	3.24
Residual fuel	1.23	1.16	1.09	1.08	1.16
Other petroleum 1/	5.51	5.45	5.69	5.81	5.96
Total	16.99	16.72	17.03	17.45	17.89
Supply:					
Production 2/	9.70	9.90	9.78	9.55	9.25
Net crude oil and petroleum imports (includes SPR) 3/	7.17	6.63	7.01	7.93	8.40
Net stock withdrawals	0.12	0.19	0.24	-0.03	0.24
Total	16.99	16.72	17.03	17.45	17.89
	Percent				
Net imports as a share of total supply	42.20	39.65	41.16	45.44	46.95
	Percent change from previous year				
Consumption		-1.59	1.85	2.47	2.52
Domestic production		2.06	-1.21	-2.35	-3.14
Imports		-7.53	5.73	13.12	5.93

1/ Includes crude oil product supplied, natural gas liquid (NGL), other hydrocarbons and alcohol, and jet fuel. 2/ Includes domestic oil production, NGL, and other domestic processing gains (i.e., volumetric gain in refinery cracking and distillation process).
3/ Includes both crude oil and refined products.
SPR denotes Strategic Petroleum Reserves.

Source: U.S. Department of Energy, Energy Information Administration. Short-Term Energy Outlook. DOE/EIA-0202 (93/3Q), August 1993.

At $18.77 per barrel, the consumption of most refined petroleum products is expected to increase slightly in 1994. In the transportation sector, continued slow economic growth is expected to dampen travel demand. Growth in motor-vehicle miles traveled is expected to be more than offset by continued improvements in vehicle efficiency that reduce gasoline and diesel fuel use.

The absence of any significant change in energy prices is expected to have a minimal effect on domestic production of crude oil in 1994. In an $18.77-per-barrel oil price scenario, domestic crude output is projected to decline 300,000 barrels per day in 1994 from 1993.

At $18.77 per barrel, 1994 net imports of crude oil are anticipated to increase 470,000 barrels per day to 8.4 million barrels, compared to a rise of 920,000 barrels in 1993. The expected 1994 increase largely reflects lower import rates during the first three quarters of 1993, giving a lower base of imports.

Electricity Prices and Availability

The dominant fuel used to generate electricity in the United States, coal, is projected to remain at its 1993 price to electric utilities for 1994. This is the result of continued increases in productivity and available excess coal-production capacity which offset a first-quarter price rise due to a stock buildup.

Accordingly, the price of electricity will not change appreciably. The price of electricity, in addition to being a function of the price of fuel, is dependent on interest rates (affecting the cost of capital for expansion and maintenance) and labor rates. Both rates are expected to increase minimally or not at all in 1994.

The present generating capacity for electricity is more than adequate to meet expected needs through 1994. Increases in electricity generation in 1994 are expected to be primarily from coal. Coal generating capacity is expected to continue increasing (at about 0.2 percent per year), while growth in nuclear generation is constrained. Hydroelectric generation is expected to rebound in 1994 due to a return to normal rainfall in the Pacific Northwest, where more than one-half of U.S. hydroelectric capacity is located.

Energy in the Farm Sector

The U.S. agricultural sector's energy supply and price expectations are a reflection of world crude-oil market conditions. Current world oil supplies are adequate and are expected to remain so through 1994. Fuel prices in the farm sector decreased in 1992 from 1991, and increased slightly in 1993 over 1992, for the first three reporting periods. For 1994 they are likely to stabilize at, or slightly above, 1993. Farmers can expect plentiful supplies of gasoline, diesel fuel, and liquefied petroleum (LP) gas this year.

Little shift is expected in the input mix (i.e., fuel choice) over the next year. If crude oil prices rise, however, farmers will likely substitute relatively less expensive energy (e.g., natural gas) for refined petroleum products where possible.

Farm Fuel Use

Agricultural consumption of refined petroleum products, such as diesel fuel, gasoline, and liquefied petroleum gas, declined steadily between 1981 and 1989 (table 17). Since then, aggregate energy consumption has remained relatively constant.

Although the number of acres planted influences energy use, so do weather and other factors. For example, switching from gasoline to diesel-powered engines, adopting conservation tillage practices, changing to larger, multifunction machines, and creating new methods of crop drying and irrigation contributed to the earlier decline. No-till and mulch-till farming practices which tend to be less energy intensive, have been more widely adopted in the past few years and are as prevalent as conventional tillage practices in some parts of the United States.

With only a minimal variation in the total number of acres planted and harvested, a few significant changes in cropping practices, and somewhat lower average energy prices, 1992 farm consumption of gasoline and diesel fuel were slightly greater than their 1991 levels.

Table 17--Gallons of fuel purchased for on-farm use: 1981-1992 1/ 2/

Year	Gasoline	Diesel fuel	LP gas
	Billion gallons		
1981	2.9	3.2	1.0
1982	2.4	2.9	1.1
1983	2.3	3.0	0.9
1984	2.1	3.0	0.9
1985	1.9	2.9	0.9
1986	1.7	2.9	0.7
1987	1.5	2.9	0.6
1988	1.6	2.8	0.6
1989	1.3	2.5	0.7
1990	1.5	2.7	0.6
1991	1.4	2.8	0.6
1992	1.6	3.1	NA 3/

1/ Excludes Alaska and Hawaii.
2/ Excludes fuel used for household and personal business.
3/ Not available

Source: U.S. Department of Agriculture, National Agriculture Statistics Service, Farm Production Expenditures, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, and 1991 summaries. Data for 1992 are from the National Agricultural Statistics Service and are not elsewhere published.

Energy Prices Fell in 1992; Up in 1993

Crude oil prices (especially imported crude, because it is the marginal supply in most instances) heavily influence the prices farmers pay for refined petroleum products. Historically, each 1-percent increase in the U.S. price of imported crude oil has translated into about a 0.7-percent rise in the farm price of gasoline and diesel fuel. In 1992, gasoline prices were 3.4 percent below their 1991 average, while diesel fuel prices fell 5.7 percent. So far in 1993, gasoline prices are 0.3 percent above their 1992 average for the corresponding period and diesel fuel prices are 0.4 percent above 1992 (table 18).

Energy Expenditures Up 1992

In 1992 (the most recent period for which data are available), farm energy expenditures on gasoline, diesel fuel, LP gas, electricity, natural gas, and lubricants totaled $8.27 billion, up 14 percent from a year earlier (table 19). This increase reflects a 14.4-percent expansion in fuel and lubricant expenditures, a 13.9-percent increase in electricity expenditures for non-irrigation purposes, and a 11.0-percent rise in expenditures on electricity for irrigation.

Total electricity expenditures increased by nearly 13 percent. Lower energy prices and higher crop yields, and a slight rise in the number of acres planted and harvested in 1992 from 1991, accounted for these increases.

Table 18--Average U.S. farm fuel prices 1/

Year	Gasoline	Diesel fuel	LP gas
		$/gallon 2/	
1981	1.29	1.16	0.70
1982	1.23	1.11	0.71
1983	1.18	1.00	0.77
1984	1.16	1.00	0.76
1985	1.15	0.97	0.73
1986	0.89	0.71	0.67
1987	0.92	0.71	0.59
1988	0.93	0.73	0.59
1989	1.05	0.76	0.58
1990	1.17	0.94	0.83
1991	1.19	0.87	0.75
1992	1.15	0.82	0.72
Jan 1992	1.08	0.77	0.75
April 1992	1.11	0.79	0.71
July 1992	1.21	0.84	0.69
Oct 1992	1.19	0.86	0.73
Jan 1993	1.13	0.80	0.86
April 1993	1.15	0.82	0.78
July 1993	1.13	0.79	0.73

1/ Based on surveys of farm supply dealers conducted by the National Agricultural Statistics Service, USDA.
2/ Bulk delivered. The gasoline and LP gas prices include federal, state, and local per gallon taxes. The diesel fuel price excludes states road taxes and the federal excise tax and includes states and local per gallon taxes where applicable.

Table 19--Farm energy expenditures

Item	1988	1989	1990	1991	1992
			$ billion		
Fuels and lubricants:					
Gasoline	1.42	1.44	1.65	1.50	1.72
Diesel	2.12	2.12	2.42	2.34	2.65
LP gas	0.38	0.38	0.53	0.44	0.65
Other	0.53	0.51	0.57	0.65	0.63
Electricity:					
Excluding irrigation	2.17	1.69	1.65	1.57	1.78
For irrigation	0.48	0.64	0.65	0.76	0.84
Total	7.10	6.78	7.47	7.25	8.27
Percent change from preceding year		-4.51	10.18	-2.95	14.07

Source: U.S. Department of Agriculture, National Agriculture Statistics Service, Farm Production Expenditures, 1987, 1988, 1989, 1990, and 1991 summaries. Data for 1992 are from the National Agricultural Statistics Service and are not elsewhere published.

Impact of the Midwest Flooding and Southeast Drought on Farm Fuel Use

Adverse weather conditions are expected to significantly impact agricultural energy consumption in 1993. First, due to flooding and excess moisture in the upper Mississippi and lower Missouri Valleys, the planted and anticipated harvested acreage for corn and soybeans have been reduced. For corn, based on the October 12, 1993, *Crop Production Report* of the U.S. Department of Agriculture, the forecast planted acreage of 73.7 million acres has been lowered from the 74.3 million acres in the June 30, 1993 *Crop Production Report* and is below the 79.3 million acres in 1992/1993. For soybeans, the forecast planted acreage of 59.5 million acres is down from the 61.6 million acres in June but is virtually unchanged from 59.1 million acres in 1992/1993.

Harvested acreage is expected to show a bigger change than planted acreage because some crops were already in the ground when the moisture came. Thus, corn harvested acreage is expected to decline from 72.1 million acres in 1992/1993 to 64.0 million acres in 1993/1994. Soybean harvested acreage is anticipated to decline from 58.4 million acres in 1992/1993 to 56.3 million acres in 1993/1994.

The second adverse weather condition affecting energy consumption this year is the drought in the Southeast United States. This will not only affect soybean output in the Southeast, but will impact the output of cotton in South Carolina, Georgia, and Alabama. However, the decline in expected harvested acreage of cotton is being more than made up for by an overall increase in planted acreage nationally. The net effect of the drought will be a decline in the average cotton yield from 680 pounds in 1992/1993 to 668 pounds in 1993/1994 with a slight increase in harvested acreage from 11.1 million acres to 13.3 million acres.

Given these considerations, the drought is expected to have little or no perceptible impact on energy consumption, since planted and harvested acreage impacts energy use while yield has little measurable effect. The flood in the Midwest, on the other hand, will have a measurable effect on agricultural energy use.

Planting and harvesting activities are significant energy users. They include preplanting, planting, cultivating, harvesting, fertilizer application, pesticide application, farm pickup, and irrigation. In fact, nearly 77 percent of the diesel fuel and 80 percent of gasoline consumed on farms are for these activities. Consequently, a reduction in these will lead to an overall lessening of farm fuel use. Further, fewer planting and harvesting activities will reduce the need for irrigation and post-harvest operations such as crop drying. These activities rely heavily on liquefied petroleum gas. Nearly 57 percent of the liquefied petroleum gas consumed on the farm is accounted for by such activities.

What does the unusually wet weather in the Midwest portend for farm fuel use in 1993? The empirical relationships between planted and harvested acreage and different types of farm fuel use have been previously established using hypothesized relationships between individual energy types and various factors that are important in explaining the variations in energy use. These factors include, in addition to planted and harvested acreage, the price of energy (e.g., diesel fuel), the price of competing types of energy (e.g., gasoline), the stock of energy using machinery and equipment, and precipitation (1,2).

Because of the flooding in the Midwest, it is expected that in 1993 farm diesel fuel consumption will decline by 122 million gallons or 3.8 percent relative to what was expected prior to the flooding. In addition, gasoline consumption will fall by 78 million gallons or 4.9 percent, and liquefied petroleum consumption will be reduced by 11.1 million gallons or 1.8 percent. These anticipated reductions are attributed solely to the effects of the Midwest flooding on planted and harvested acreage.

References

1. N.D. Uri and M. Gill, "Demand for Gasoline and Diesel Fuel by Farmers in the United States," *International Journal of Energy Research*, Vol. 15 (1991), pp. 289-299.

2. N.D. Uri and M. Gill, "The Agricultural Demand for Natural Gas and Liquefied Petroleum Gas in the United States," *The Journal of Energy and Development*, Vol. 15 (1990), pp. 257-274.

Farm Machinery Purchases Up

More farm machinery was purchased in the United States in the first 8 months of 1993 than for the same period of 1992, due to increased farm income, lower interest rates, higher asset values, and lower farm debt.

Monthly tractor and combine purchases from January through July 1993 increased over the same months in 1992. Sales are expected to remain strong through the end of 1993.

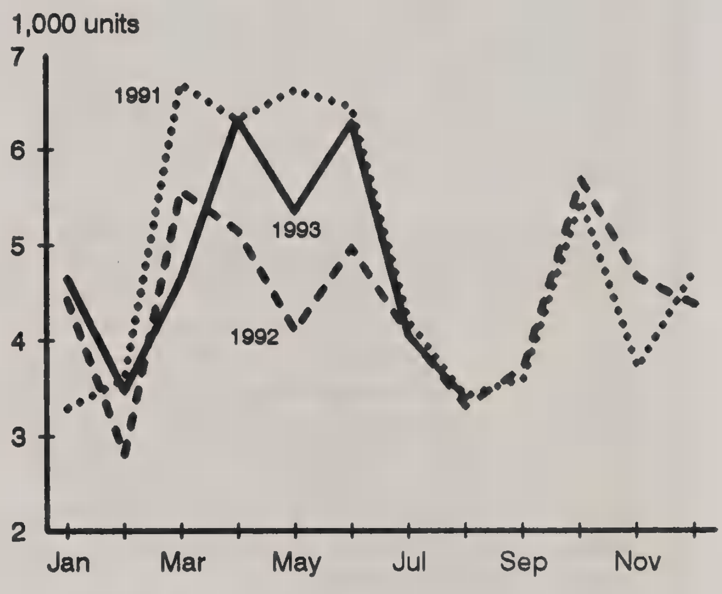
Unit Sales Up in 1993

Sales of farm tractors and combines increased during the first 8 months of 1993, compared to 1992 (figure 3). However, sales were still below those of 1991. Farm tractor sales through August 1993 totaled 38,144 units, compared to 34,388 units for the first 8 months of 1992, and 40,586 units for 1991.

Total tractor purchases are forecast to be up 8 percent in 1993, an increase from the 2 percent forecast in February (table 20). Most factors affecting machinery demand currently favor increased equipment purchases. While farm income was up in 1992, machinery purchases tended to lag behind farm income, which is a positive factor for 1993. The value of farm assets is up and will probably continue to increase in 1993. The debt to asset ratio, 16.1 in 1992, should hold steady through 1993. Interest rates are the lowest since 1962 and continue to decline, another positive factor for increased purchases.

Tractor sales in the 40-100 horsepower category increased 4.3 percent through August 1992-93 and are forecast to end the year with a 1 percent increase. Tractors in the 100-and-over horsepower category increased 24.4 percent and are forecast to end the year with a 22 percent increase. Historically, when sales of all tractors increase, large (over 100 horsepower) tractor sales go up proportionately more

Figure 3
Farm Tractor Sales



Wheel tractors, 40 horsepower and above.
Source: Equipment Manufacturers Institute.

Table 20--Domestic farm machinery unit sales

Machinery category	1986	1987	1988	1989	1990	1991	1992	1993F	Change 91-92	Change 92-93
	Units								Percent	
Tractors:										
Two-wheel-drive										
40-99 hp	30,800	30,700	33,100	35,000	38,400	33,900	34,500	34,800	2	1
100-139 hp 1/	5,100	5,100	4,300	5,200						
Over 139 hp 1/	9,100	10,800	11,800	15,400						
Total over 99 hp	14,300	15,900	16,100	20,600	22,800	20,100	15,600	19,100	-22	22
Four-wheel-drive	2,000	1,700	2,700	4,100	5,100	4,100	2,700	3,000	-35	11
All farm wheel tractors	47,100	48,400	51,700	59,700	66,300	58,100	52,800	56,900	-9	8
Grain and forage harvesting equipment:										
Self-propelled combines	7,700	7,200	6,000	9,100	10,400	9,700	7,700	8,200	-21	6
Forage harvesters 1/2/	2,200	2,300	2,400	2,800						
Haying equipment:										
Mower conditions 1/	10,900	11,200	11,000	13,200						

1/ Discontinued after 1989. 2/ Shear bar type.
P-preliminary. F-ERS forecast.

Source: Equipment Manufacturers Institute (EMI).

than the smaller (40-100 horsepower) category. The reverse occurs when overall tractor sales are down. Proportionately fewer large tractors are sold when total sales decline. Demand factors appear to be favorable for increased purchases of tractors and farm machinery in coming months and purchases in the larger horsepower categories will probably increase proportionately more.

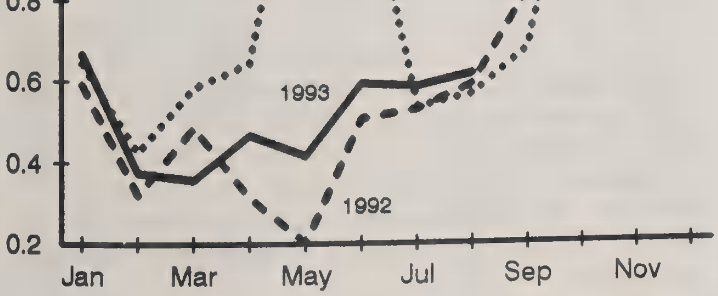
Combine sales also were up January through August 1993, compared to last year, but did not reach the higher sales of 1991 (figure 4). Sales through August totaled 4,083 units compared to 3,547 units in 1992 and 5,875 units in 1991. Combine sales are expected to increase by 6 percent by the end of 1993.

Farm Economy

Several farm sector economic factors started to improve in 1992 and the trends appear to be continuing in 1993. They affect the demand for farm machinery and are expected to encourage increased capital investment in coming months. Nominal and real interest rates were the lowest in several years. The value of farm assets was up. Farm debt was down $500 million from 1991. Farm equity increased, which improved farmers' ability to borrow. In addition, farm income was up in 1992 due to bumper grain crops. All of these factors encouraged increased investment in farm machinery. Some factors are lagged; that is, the effect of higher incomes, for example, may not have the effect of increasing capital investment until several months later.

Not all economic indicators favor increased purchases. Farm machinery prices rose significantly the first 7 months of 1993. Also some commodity prices, such as wheat, rice and sorghum, have fallen the last several months, affecting farmers raising those crops.

Figure 4
Combine Sales



Self-propelled combines
Source: Equipment Manufacturers Institute.

Floods in the Midwest will have a mixed effect. To the extent that farmers can afford to replace equipment damaged by water, demand will increase. However, many farmers who lost crops, and consequently, income, will have to put off replacing damaged equipment and try to survive by renting or borrowing until their situation improves.

Farmers not affected by floods may have late harvests, delaying planned machinery purchases. Rain and cool weather have delayed the ripening of many crops, causing some to be damaged by early frosts. Some parts of the country, especially the Southeast, suffered from drought that will likely dampen farm machinery purchases in those areas.

Another factor that will affect the environment, and possibly prices of farm machinery, is the new EPA regulation to limit exhaust emissions (1). The rules will eventually affect all engines 50 horsepower and higher. The regulation goes into effect in 1996 for engines 175-750 horsepower (HP), 1997 for 100-175 HP, 1998 for 50-100 HP, and the year 2000 for engines over 750 HP. The EPA proposes to limit nitrogen oxides emissions to 9.2 grams per kilowatt-hour and estimates that modifications to meet that standard would cost about $170 per engine. At present, the standard only applies to nitrogen oxides, but standards may be set for hydrocarbon emissions once a suitable hydrocarbon testing procedure is developed.

Factors Affecting Sales

Demand for farm machinery is the result of a combination of many factors. Farm income, total value of farm assets, debt, interest rates, number of acres cropped, the age of machinery on farms, and many other factors play a part in shaping the demand for farm machinery.

Interest Rates

Lower interest rates have a positive effect on farm machinery investments. The real (adjusted for inflation) prime rate was 3.7 percent in 1992 (table 21). By the second quarter 1993, it had fallen to 3.4 percent. The prime rate correlates with changes in the nominal machinery loan rate, which has decreased every year since 1989. Farm machinery and equipment loan rates were down to 9.3 percent (6.7 percent real rate). While the real rate reflects the actual cost of borrowing, the nominal rate probably has a more direct effect on machinery purchases because it is more obvious to farmers. Interest rates are negatively correlated with purchases of farm machinery. As interest rates fall, the total cost of machinery bought on credit decreases, facilitating increased purchases.

Cash Receipts, Expenses, and Income

Cash receipts were up in 1992 to $171 billion. Cash receipts are a combination of crop and livestock sales. Crop sales were up 3.7 percent from 1991, to $85 billion, an all-time high. Cash receipts were dampened somewhat by a decrease in livestock receipts from $86.8 to $86 billion from 1991 to 1992.

Table 21--Trends in U.S. farm investment expenditures and factors affecting farm investment demand

Item	1988	1989	1990	1991	1992P	1993F
				$ billion		
Capital expenditures:						
Tractors	2.54	2.90	3.12	2.59	2.8	2.7-3.1
Other farm machinery	4.22	5.09	5.59	5.41	5.1	5.1-5.4
Total	6.76	7.99	8.71	8.00	7.9	7.8-8.5
Tractor and machinery repairs	4.02	5.41	4.37	4.48	4.2	4.2-4.6
Trucks and autos	2.36	2.58	2.62	2.39	2.3	2.3-2.5
Farm buildings 1/	2.39	2.53	2.80	2.75	2.4	2.3-2.7
Factors affecting demand:						
Interest expenses	14.3	13.8	13.3	12.1	11	10-14
Total production expenses	137.0	144.0	149.9	150.3	149	150-152
Farm business assets:						
Real estate assets 2/	595.5	615.7	628.2	623.2	633.1	640-650
Nonreal estate assets 2/	205.6	214.1	220.2	220.7	228.1	225-235
Farm business debt 2/ 3/	139.4	137.2	136.8	138.8	138.3	137-143
Agricultural exports 4/	35.4	39.6	40.1	37.5	42.3	42.5
Cash receipts	151.2	161.2	170.0	168.7	171	170-177
Net farm income	38.8	46.9	46.5	40.0	48	43-50
Net cash income	54.5	54.7	55.9	53.3	57	58-67
Direct government payments	14.5	10.9	9.3	8.2	9	11-15
				Million acres		
Idled acres 5/	77.7	60.8	61.6	64.5	54.9	56
				Percent		
Real prime rate 6/ 7/ 8/	5.4	6.5	5.7	4.4	3.7	3.4
Nominal farm machinery and equipment loan rate 7/ 8/	11.7	12.8	12.3	11.3	9.3	8.6
Real farm machinery and equipment loan rate 6/ 8/	8.4	8.4	8.0	7.2	6.7	6.0
Debt-asset ratio 9/	17.4	16.5	16.1	16.4	16.1	15-17

1/ Includes service buildings structures, and land improvements. 2/ Calculated using nominal dollar balance sheet data, excluding farm households, for December 31 of each year. 3/ Excludes CCC loans. 4/ Fiscal year. 5/ Includes acres idled through commodity programs and acres enrolled in the Conservation Reserve Program. 6/ Deflated by the GDP deflator. 7/ Average annual interest rate. From the quarterly sample survey of commercial banks: Agricultural Financial Databook, Board of Governors of the Federal Reserve System. 8/ 2nd quarter 1993. 9/ Outstanding farm debt divided by the sum of farm real and nonreal estate asset values.
P-preliminary. F-forecast.

Source: Agricultural Income and Finance, Situation and Outlook Reports, and other ERS sources.

Total expenses were nearly unchanged from 1990 to 1992, at about $150 billion per year. Decreases in total interest expenses were balanced by increases in other production expenses, such as pesticides. Marketing, storage, and transportation expenses were also up slightly in 1991, and again in 1992.

Net farm income, the difference between gross cash income and total expenses, was up significantly from $40 to $48 billion from 1991 to 1992. Higher farm income typically has a positive effect on farm machinery purchases, although the effect may be lagged several months.

Farm Assets, Debt, Equity, the Debt-Asset Ratio

Business equity was about $723 billion in 1992. Assets are composed of both real estate and non-real estate items, including livestock and machinery. Total assets are forecast to increase again in 1993 due largely to a substantial expected increase in real estate values.

Farm business debt dropped $500 million from 1991 to 1992. Lower debt improves farmers' borrowing position with lenders. Farm equity, the net worth of the farm sector, is derived from total assets, minus debt. Total farm equity increased in 1992. Increased equity implies more collateral to finance farm machinery loans.

Balance sheet components are now reported by the Economic Research Service (ERS) on a "farm business" basis (2). ERS used to report two versions of assets and debt, "including" and "excluding" households. The series that excluded households was similar to the new farm business series on assets and debts. The including households series used to be shown here because lenders look at a farmer's total assets and debt when considering loan applications. The growth in importance of off-farm income has made it more difficult to separate farm household accounts between farm and nonfarm activities and prompted the shift to the farm business series. Since the including and excluding households accounts closely paralleled each other, the new business series would likely make little difference when used as a demand factor for farm machinery investments.

A common indicator of the economic health of the farm sector is the debt-asset ratio. The lower the debt-asset ratio, the more favorable the borrowing position of farmers.

The ratio was 16.1 in 1992 and is expected to hold steady in 1993. This is the lowest debt-asset ratio since the early 1960's.

Prices

Farm machinery and equipment prices rose in 1992 and again in 1993 (table 22). The July 1993 prices-paid index (1977=100) for tractors was 223, 6 points above July 1992. Prices for other machinery and trucks rose 9 and 13 points, respectively. However, the price index for all production items rose only 3 points, primarily due to declines in prices of fertilizer, fuels, and interest rates. Increases in farm machinery prices have a dampening effect on demand. While prices paid for farm machinery increased 13 points, the July 1992-93 prices-received index for all farm products rose only 2 points, from 138 to 140 (1977=100).

Commodity Exports

Another factor that affects purchases of farm machinery is commodity exports. Commodity exports were $42.3 billion in 1992, up $4.8 billion from 1991. The 1993 forecast is up slightly at $42.5 billion. At that level, commodity exports would be the highest in the last 5 years. Wheat, feedgrains, and oilseeds, compose the major portion of commodity exports. The upward trend in commodity exports is expected to favor increased investment in farm machinery.

Machinery Purchases and Depreciation

Depreciation of farm machinery has exceeded capital expenditures every year since 1980 in the United States. This phenomenon is known as capital depletion and was most pronounced in the mid 1980's. In 1985 real depreciation reached $8.5 billion and real capital expenditures were $4.2 billion, a gap of $4.3 billion (figure 5). The gap narrowed to $.7 billion in 1990 and then increased again to $1.3 billion in 1992.

Table 22--Prices paid for trucks, tractors, and other farm machinery

Year	Trucks and autos	Tractors and self-propelled machinery	Other machinery	Production items, interest, taxes, & wage rates
		1977 = 100		
1980	123	136	132	139
1981	143	152	146	151
1982	159	165	160	158
1983	170	174	171	159
1984	182	181	180	161
1985	193	178	183	156
1986	198	174	182	150
1987	208	174	185	152
1988	215	181	197	160
1989	223	193	208	167
1990	231	202	216	172
1991	244	211	226	175
1992 July	262	217	234	177
1993 July	275	223	245	180

Source: National Agricultural Statistics Service, USDA.

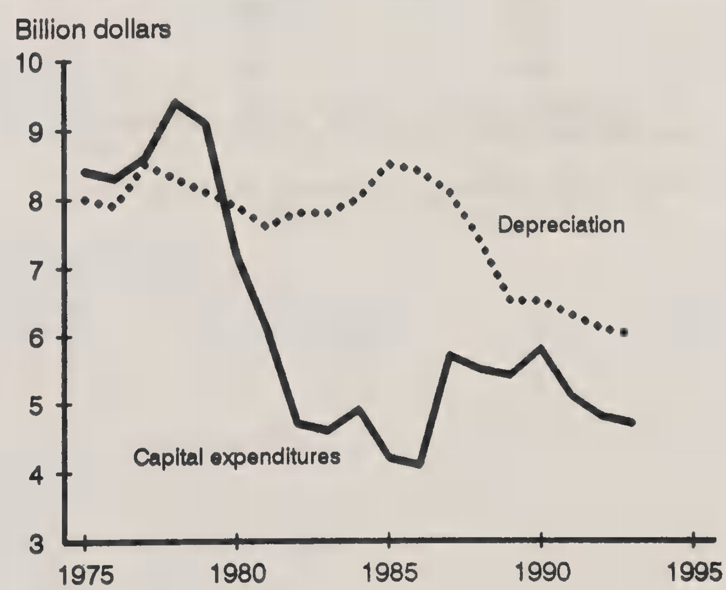
Capital depletion in agriculture is probably the result of several factors. Tillage practices are changing from conventional operations, consisting of many passes over the fields, to conservation tillage or no-till to help conserve soil. Federal law requires farmers to have conservation plans operational by 1995. Many farmers already have fully operational plans. Conservation tillage and no-till require the soil to be tilled less often. Fewer trips over the fields results in fewer hours of equipment use which means equipment lasts longer (it is the hours of use, not age, that wears out machinery). With rising machinery and equipment prices, some farmers welcome tillage practices that make machinery last longer.

Farming in the late 1970's was profitable, which encouraged farmers to buy tractors and machinery, sometimes more and larger units than needed. When farm income declined in the early 1980's, farmers bought less machinery, but the farming sector remained highly productive by keeping old machinery in repair and using the extra capacity built up during the late 1970's. Although delaying expenditures on farm machinery can incur higher repair costs, there is usually a range of time when the difference in cost between keeping an old machine and buying a new one is small.

Eventually, capital investment should equal or surpass depreciation. Capital depletion can not continue indefinitely, however, no one knows when capital expenditures will exceed depreciation. Capital expenditures seemed to be catching up with depreciation in the late 1980's, but turned down again in 1991. As more farmers invest in the specialized machinery needed to comply with the 1995 farm plans required by Federal conservation regulations, perhaps capital expenditures will again exceed depreciation. This may have started with increased capital expenditures in the first seven months of 1993.

Figure 5

Machinery Capital Expenditures and Depreciation



Adjusted to 1975 dollars.
1993 estimated.

Capacity Utilization

The farm machinery industry plant capacity was 66 percent for both 1989 and 1990 (table 23). While the industry was not operating near full capacity, 66 percent is much higher than the 24 percent capacity rate in 1986. The low in 1986 followed several years of low demand for farm machinery and high inventories. These percentage capacity rates are for the fourth quarter of each year, which is traditionally a slack period of farm machinery production, and therefore may be below the yearly averages.

Capacity rates may be misleading from another aspect. Total, or full production capacity has decreased over the past decade as firms in the industry have cut back, consolidated, and combined in response to low demand. The same capacity utilization rate in the 1970's would have meant more production since full production capacity for the industry was higher. Actually, capacity utilization in the 1970's was also higher, 83-85 percent throughout the 1970's as the farm machinery industry responded to high demand caused by high farm incomes, large exports, and high real estate asset values (3).

Farm Machinery Trade

Tractors, combines, livestock equipment, other farm machinery, and component parts are exported from the United States all over the world. Tractors accounted for over one-half of all U.S. imports of farm machinery (table 24).

Total U.S. exports of farm machinery was estimated at $3.2 billion in 1992, according to the U.S. Department of

Table 23--Plant capacity, farm machinery and equipment industry (fourth quarter)

Year	Capacity utilization rates 1/
	Percent
1980	62
1981	48
1982	31
1983	38
1984	41
1985	37
1986	24
1987	43
1988	54
1989	66
1990	66

1/ For 1989 and 1990, percent of full production. For 1988 and earlier, percent of "practical capacity."

Source: U.S. Bureau of the Census. Survey of Plant Capacity. MQ-C1(90)-1, 1992

Table 24 --Farm machinery exports and imports.1/

Item	1991	1992	January-July 1992	January-July 1993
	Million dollars			
Exports:				
Total	1,556	1,706	1,059	1,188
Tractors 2/				
Tractors, 40-100 HP	12	18	11	13
Tractors, over 100 HP	335	355	244	269
Tractors, used	84	76	51	48
Other misc. tractors	65	81	42	59
Combines and harvesters	279	283	178	213
Balers	59	65	42	41
Mowers	46	47	36	38
Haying equipment	23	23	16	28
Plows 3/	11	10	6	7
Disk harrows	5	6	4	6
Cultivators and tillers	52	67	41	58
Spraying equipment	22	24	14	13
Seeders and planters	29	34	23	31
Fertilizing equipment	22	22	14	16
Cleaning and grading equip	14	19	10	7
Livestock equipment	320	383	225	234
Parts and components	177	190	103	111
Imports:				
Total	1,606	1,633	1,005	1,070
Tractors 2/				
Tractors, 40-100 HP	547	569	353	344
Tractors, over 100 HP	172	188	99	78
Tractors, used	46	38	24	33
Other misc. tractors	251	241	144	190
Combines and harvesters	57	54	37	42
Balers	8	6	4	4
Mowers	60	60	43	43
Haying equipment	14	7	5	9
Plows 3/	20	11	7	7
Disk harrows	33	24	12	11
Cultivators and tillers	44	38	24	30
Spraying equipment	32	38	29	26
Seeders and planters	19	26	14	32
Fertilizing equipment	14	15	9	10
Cleaning and grading equip	6	4	3	8
Livestock equipment	82	90	51	63
Parts and components	200	224	147	138

1/ Some items may not be comparable to previous data due to reclassification.
2/ Excludes crawler tractors.
3/ Includes moldboard, disk and other plows.

Source: Official statistics of the U.S. Department of Commerce.

Table 25--U.S. farm machinery trade situation, 1986-92

Year	Shipments	Exports	Imports	Trade surplus	Domestic supply	Shipments exported	Domestic supply imported
	$ billion					Percent	
1989	10.4	2.9	2.3	0.6	9.8	28	23
1990	11.5	3.2	2.6	0.6	10.9	27	23
1991	11.2	3.0	2.0	1.1	10.1	27	19
1992E	9.9	3.2	1.9	1.3	8.6	32	22
1993F	10.0	3.3	1.8	1.5	8.5	33	22

E-estimated. F-forecast.

Source: U.S. Industrial Outlook 1993, International Trade Administration.

Commerce (USDC), up 6.2 percent from 1991 (table 25). The biggest trading partner for both imports and exports is Canada. Major export markets included Mexico, Saudi Arabia, Spain, France, and Japan. More than one-fourth of the machinery manufactured in the U.S. is exported (4). Exports, as a percent of U.S. shipments, have been increasing since 1989 and are forecast to reach 33 percent in 1993.

Farm machinery imports have declined since 1991. Imports for 1992 were $1.9 billion, a decline of 4.1 percent from 1991. More than 60 percent of U.S. farm machinery imports are tractors and parts, mostly for below-100-horsepower tractors according to USDC. Major suppliers of imports were Canada, Mexico, Germany, Italy, the United Kingdom, and Japan. Imports, as a percent of domestic supply, have held at 22-23 percent from 1989 to 1992, dipping to 19 percent in 1991.

The trade surplus in farm machinery was $1.1 billion in 1991. In 1992 it was about $1.3 billion. Exports of farm machinery have exceeded imports for the last 4 years. The outlook for 1993 is for another increase in exports to about $3.3 billion and a slight decrease in imports to about $1.8 billion, for a trade surplus of $1.5 billion.

References

1. *Short Liner*. Farm Equipment Manufacturers Association. May 15, 1993.

2. Erickson, K. and others. *Farm Business Balance Sheet, 1960-91, United States and by State*. SB-856. U.S. Dept. of Agr., Econ. Res Serv., 1993.

3. Sisco, C., and L. Hansen. "Farm Machinery," *Seven Farm Input Industries*. AER-635. U.S. Dept. of Agr., Econ. Res. Serv., 1990.

4. Wiening, M.R. "Farm Machinery," *U.S. Industrial Outlook 1993*. U.S. Dept. of Commerce, International Trade Administration. January 1993.

Seed Consumption Unchanged, but Prices-paid Index Rose in 1993

In the 1992/93 crop year, seed use for eight major crops remained unchanged from the previous year. The prices-paid index, on the other hand, rose 4 percent in 1993.

Consumption

In the 1992/93 crop year, total seed use for eight major crops was 5.9 million tons, very close to the previous year's seed consumption of 6 million tons (table 26). In 1993, soybean and wheat planted acreage remained largely unchanged and the increased barley, oats, and cotton planted acreage was offset by the decreased corn, sorghum, and rice planted acreage. As a result, total seed consumption for eight major crops did not change much from a year earlier.

Planted acreage is the major factor which affects the variation in seed use. Seeding rates per acre, which change very slowly over time, are also an important determinant of seed consumption.

Table 26--Seed use for major U.S. field crops 1/

Crops	1989/90	1990/91	1991/92	1992/93 2/	1991/92-1992/93
	1,000 tons				% change
Corn	529	540	566	524	-7
Sorghum	36	39	48	39	-18
Soybeans	1,664	1,701	1,700	1,705	0
Barley	324	350	310	317	2
Oats	374	306	285	288	1
Wheat	3,009	2,709	2,811	2,778	-1
Rice	180	195	190	180	-5
Cotton 3/	94	108	102	106	4
Total	6,210	5,948	6,012	5,937	-1

1/ Crop marketing year. 2/ Preliminary. 3/ Upland cotton.

Prices

In 1993, all field seed prices paid by farmers, except rice seed, were higher than those of the previous year. As a result, USDA's price-paid index for all seeds rose to 169 in 1993 from 165 in 1992. Rice seed price, however, fell 7 percent from last year (table 27). The lower rice seed price in the U.S. is due to lower world market prices, which, in turn, is due to large rice stocks in the international market.

Forage seed prices in 1993 rose compared to 1992. In 1993, an additional, 1.1 million cropland acres are likely to be enrolled in Conservation Reserve Program (CRP), an increase of 10 percent from the previous year. Higher CRP-related grass demand and lower seed stocks contributed to higher forage seed prices. For example, red clover, tall fescue, orchard grass, annual ryegrass, timothy, and alfalfa

Table 27--April farm planting seed prices 1/

Item	Unit	1990	1991	1992	1993	Change 92-93
						%
Field seeds:						
Corn	2/	69.90	70.20	71.80	72.70	1
Grain sorghum	$/cwt.	69.90	71.20	72.30	74.50	3
Oats	$/bu.	4.19	3.71	4.26	4.86	14
Barley	$/bu.	5.25	4.55	5.10	6.29	23
Wheat (spring)	$/bu.	6.05	4.72	6.06	7.66	26
Wheat (winter)	$/bu.	8.01	6.89	7.41	8.19	11
Soybeans	$/bu.	12.50	12.80	12.40	12.60	2
Cotton	$/cwt.	54.30	58.20	59.70	62.70	5
Potatoes	$/cwt.	11.00	9.70	6.95	8.60	24
Rice	$/bu.		14.40	16.50	15.40	-7
Forage seeds:						
Red clover	$/cwt.	145.00	134.00	122.00	148.00	21
Fescue, tall 3/	$/cwt.	85.10	89.00	67.80	87.00	28
Orchardgrass	$/cwt.	102.00	101.00	100.00	122.00	22
Ryegrass, annual	$/cwt.	50.50	46.80	43.80	56.70	29
Timothy	$/cwt.	82.10	66.40	66.30	80.60	22
Lespedeza, sericea	$/cwt.	134.00	101.00	92.80	89.70	-3
Alfalfa, proprietry	$/cwt.	253.00	266.00	252.00	269.00	7
Seed price paid index (1977=100)		163	163	162	169	4

1/ Derived from the April survey of farm supply dealers conducted by NASS, USDA. 2/ $/80,000 kernels. 3/ Alta and Kentucky 31.

prices rose 21, 28, 29, 22, and 7 percent, respectively (table 27).

Expenditures

In 1992, total farm seed expenditures was 4.9 billion dollars, up 12 percent from 1991 expenditures of 4.4 billion dollars. This was because field-crops and small grain seed expenditures rose 26 percent due to sharp increases in their prices (table 28). Increased planted acreage in 1992 also contributed to the higher total farm seed expenditures. In 1993, prices of all field-crop and small grain seed, which constitute the major component of total seed expenditures, have increased sharply. As a result, farm seed expenditures in 1993 are likely to be higher than 1992.

Fall Potato Seeding Rates and Seeding Cost Per Acre in 1992

In 1992, 11 predominantly fall potato growing States planted 80 percent of the total fall potato acreage. The average seeding rate in 1992 was 20 cwt per acre, the same as for the 2 previous years. However, potato seeding rates among surveyed states vary widely because of moisture conditions. States such as Maine and New York, where moisture is available due to adequate rainfall, support higher seeding rates. In Colorado, Oregon, and Washington, seeding rates are also higher because potatoes are grown on irrigated land. States with less moisture, on the other hand, tend to have much lower seeding rates. For example, North Dakota and Minnesota producers, in 1992, had an average seeding rate of 16 and 17 cwt per acre, respectively (table 29).

Seeding rates and seed prices are the major determinants of seed cost. In 1992, the average cost per acre was $141, down 24 percent from a year earlier due primarily to a decline of 28 percent in price. Among surveyed States, per acre cost ranged from $84 for North Dakota to $251 for New York, due to differences in seed potato prices and seeding rates per acre. Average seed cost per acre in 1993 is likely to rise because of higher prices.

Table 28--U.S.farm expenditures for seeds 1/

Item	1988	1989	1990	1991	1992 2/	Change 91-92
			Billion $			%
Field crops and small grains	2.49	2.77	2.67	2.84	3.57	26
Legumes, grasses, and forages	0.34	0.34	0.33	0.28	0.33	18
Seeds and plants for other crops	0.78	0.67	0.88	1.17	0.84	-28
Other seed expenses 3/	0.09	0.08	0.05	0.08	0.14	75
Total seed expenditures	3.69	3.86	3.93	4.37	4.88	12

1/ Excludes bedding plants, nursery stocks, and seed purchased for resale.
2/ Unpublished survey indications.
3/ Includes seed treatment.

Source: U.S. Department of Agriculture, NASS.

Potato growers used purchased seed potatoes on 86 percent of the 1992 fall potato crop. However, in Colorado, growers used homegrown seed potato on half of the potato acreage. Colorado producers grew a large share of their own seed, which is typically one or two generations away from certified seed.

Winter Wheat Seeding Rates and Seed Cost Per Acre in 1993

The average winter wheat seeding rate was 72 pounds per acre in 1993, 1 pound less than 1992. The average seeding cost per acre was $8.25, slightly lower than 1992 because of the lower seeding rate (table 30).

Table 29--Fall potato seeding rates, seed cost per acre, and percent purchased, 1992 1/

States	Acres planted 2/	Rate per acre	Cost per acre 3/	Acres with purchased seed
	1,000	Cwt	$	%
Colorado	67	25	178	52
Idaho	380	21	121	90
Maine	81	22	186	71
Michigan	37	20	175	88
Minnesota	71	17	115	76
New York 4/	21	25	251	74
North Dakota	145	16	84	94
Oregon	45	22	177	90
Pennsylvania	20	20	237	95
Washington	125	22	191	99
Wisconsin	66	20	133	84
1992 Average	1,058	20	141	86
1991 Average	1,116	20	186	85
1990 Average	1,087	20	224	85

1/ States in survey planted 80 percent of the fall potato acreage in 1992. 2/ Preliminary. 3/ Based on data from those farmers who used purchased seed. 4/ Excludes Long Island.

Table 30--Winter wheat seeding rates, seed cost per acre, and percent of seed purchased, 1993 1/

States	Acres	Rate per acre	Cost per acre 2/	Acres with purchased seed
	1,000	lbs.	$	%
Colorado	2,550	48	4.16	41
Idaho	850	94	12.68	70
Illinois	1,550	107	15.62	61
Kansas	11,300	62	6.32	25
Missouri	1,400	117	14.25	51
Montana	2,500	58	5.58	33
Nebraska	2,100	64	5.42	28
Ohio	1,000	134	20.18	63
Oklahoma	5,500	75	6.09	33
Oregon	860	75	10.16	69
South Dakota	1,400	71	5.93	35
Texas	3,700	76	7.19	38
Washington	2,500	65	7.45	81
1993 average	37,210	72	8.25	40

1/ Preliminary. States listed harvested 84 percent of U.S. winter wheat acres in 1993. 2/ Based on data from those farmers who used purchased seed.

Seeding rates and costs per acre vary widely among 13 surveyed States. Ohio, Illinois, Missouri, and Idaho had higher seeding costs because of higher rates. Among these States Ohio had the highest seeding cost, $20.18 per acre, because of the highest seeding rate of 134 pounds per acre. Colorado, on the other hand, had the lowest seeding cost, $4.16 per acre due to the lowest seeding rate of 48 pounds per acre.

Farmers used purchased seed on an average of 40 percent of the 1993 winter wheat acreage, which was close to the 1992 average of 39 percent. Washington showed the highest (81 percent) and Nebraska the lowest (28 percent). Local economic situations, prices, and yield of purchased seed apparently account for much of the regional variations.

U.S. Corn Seed Exports

The volume of U.S. field corn seed exported to 12 leading importers fell to 71,947 metric tons, a 12-percent decline from 1991. These countries accounted for 92 percent of U.S. total corn seed exports in 1992 (table 31). Although exports to Canada, Mexico, France, Italy, and Spain rose 8, 57, 27, 10, and 37 percent respectively, sharp declines in exports to Germany, Netherlands, Greece, and Former Soviet Union (FSU) more than offset these increases. As a result, U.S. corn seed exports to all countries fell 16 percent in 1992.

In 1993, the volume of U.S. corn seed exports to major importers rose to 32,226 metric tons in the first 6 months, an increase of 5 percent over the corresponding period in 1992 (table 31). Although exports to FSU, Romania, Spain, and Italy declined in the first half of 1993 over the corresponding 1992 period, these declines were offset by the increased shipments to Canada, Mexico, Germany, and France.

U.S. Corn Seed Imports

In 1992, Canada, Argentina, Chile, and Hungary, the major suppliers of corn seed imports, supplied 26,015 metric tons of corn seed--a 150-percent increase over a year ago. This sharp increase was attributable to large shipments of off-season production from Argentina and Chile to satisfy greater planted corn acreage in 1992 (table 32). These countries together accounted for 97 percent of total U.S.

Table 31--U.S. exports of corn seed by volume

Country	1990	1991	1992	Change 91-92	January-June 1992	January-June 1993	Change 92-93
	---Metric tons---			%	--Metric tons--		%
Canada	4,076	7,561	8,192	8	5,768	6,737	17
Mexico	10,329	7,963	12,472	57	5,760	7,908	37
France	9,666	10,953	13,859	27	2,408	3,860	60
Germany	1,796	8,822	1,670	-81	979	1,606	64
Spain	4,132	2,076	2,853	37	1,821	961	-47
Italy	20,889	21,773	23,955	10	9,809	7,303	-26
Netherlands	2,437	10,354	2,791	-73	247	135	-45
Greece	1,828	4,072	3,263	-20	2,163	2,158	0
Romania	1,050	2,532	191	-92	191	126	-34
USSR	2,459	3,569	353	-90	353	0	-100
Turkey	59	171	388	127	388	689	78
Japan	1,431	1,491	1,960	31	757	743	-2
Subtotal	60,152	81,337	71,947	-12	30,644	32,226	5
Total all countries	70,366	93,722	78,509	-16	84,234	54,937	-35

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Table 32--U.S. imports of corn seed by volume

Country	1990	1991	1992	Change 91-92	January-June 1992	January-June 1993	Change 92-93
	---Metric tons---				--Metric tons--		%
Canada	8,010	6,857	6,674	-3	1,981	4,455	56
Argentina	511	138	4,821	3393	4,804	3,787	-27
Chile	4,509	3,406	14,129	315	13,496	8,149	-66
Hungary	881	0	391	na	391	171	-129
Subtotal	13,911	10,401	26,015	150	20,672	16,562	-25
Total all countries	13,996	10,978	26,809	144	21,387	18,952	-13

na - Not applicable

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

corn seed imports in 1992. However, these imports constituted only a small part of total U.S. seed consumption.

The volume of corn seed imports from these countries, in the first 6 months of 1993, was 16,562 metric tons, a 25-percent decline compared with the corresponding period of 1992. Corn seed imports declined because of plentiful domestic seed supplies.

Soybean Seed Exports

The volume of soybean seed exports to our major trading partners declined for a second year. Soybean seed exports to 6 leading trading partners: Italy, France, Japan, Mexico, Turkey, and Canada fell 19 percent in 1991 and 9 percent in 1992 (table 33).

The volume of soybean seed exports was 52,677 metric tons, a 21-percent decline in the first 6 months of 1993, compared with the corresponding period in 1992. At the same time, total exports to all countries also declined 21 percent (table 33). U.S. soybean seed exports to Canada, France, and Japan increased in the first 6 months of 1993, compared with the same period of 1992. These gains, however, were overshadowed by a sharp decline in exports to Mexico and Italy.

Total Exports

In 1992, the value of total U.S. seed exports fell to $669 million, a decrease over 1991 of less than 1 percent. This decline primarily reflected decreases in corn and soybeans, two of the major export commodities (table 34).

Mexico, Italy, Canada, Japan, Saudi Arabia, France, and Netherlands were the top markets for U.S. planting seed in 1992. These countries together accounted for 71 percent

Table 33--U.S. exports of soybean seed by volume

Country	1990	1991	1992	Change 91-92	January-June 1992	January-June 1993	Change 92-93
	---Metric tons---			%	---Metric tons---		%
Canada	449	425	1,178	177	1,178	4,108	249
Mexico	36,731	4,827	32,674	577	31,670	18,502	-42
France	4,827	4,272	603	-86	584	2,325	298
Italy	55,937	65,571	34,500	-47	32,087	25,393	-21
Turkey	2,835	1,838	7	-100	7	14	100
Japan	2,325	6,947	7,341	6	1,083	2,335	116
Subtotal	103,104	83,880	76,303	-9	66,609	52,677	-21
Total all countries	106,991	91,004	83,585	-8	72,808	57,654	-21

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Table 34--U.S. exports and imports of seed for planting

Item	1989	1990	1991	1992	Change 91-92
	-----$ million -----				%
Exports:					
Forage	96	104	101	114	13
Vegetable	153	176	220	221	0.5
Flower	11	13	14	19	36
Corn 1/	68	138	181	177	-2
Grain sorghum	55	27	28	34	21
Soybean	54	45	41	30	-27
Tree/shrub	4	2	2	3	50
Sugarbeet	1	2	3	3	0
Other	68	81	82	68	-17
Total	510	588	672	669	-0.4
Imports:					
Forage	44	35	30	45	50
Vegetable	56	60	79	82	4
Flower	24	23	24	27	13
Corn 2/	37	18	15	35	133
Tree/shrub	2	2	2	2	0
Other	6	9	14	10	-29
Total	169	147	164	201	23
Trade balance	341	441	508	468	-8

1/ Not sweet, not food aid. 2/ Certified.

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

of the total export value (table 35). Mexico, with 18 percent of total seed export value, led the market followed by Italy with 15 percent. Italy, however, was the leader in 1991. Third position was held by Canada with 11 percent and Saudi Arabia was fourth with 8 percent.

On regional basis, North and Central America, Western Europe, and Asia typically account about 90 percent of total seed export value. In 1992, it was 89 percent (table 35).

Total Imports

In 1992, the value of total seed imports rose 23 percent compared to 1991. This increase largely reflected 50, 4, 13, and 133 percent increase in forage, vegetable, flower, and corn seed import values, respectively. As a result, U.S. net seed trade balance in 1992 declined 8 percent to $468 million from 1991 (table 34).

Canada continued to be the leading U.S. seed for planting supplier with 25 percent of total seed import value in 1992 (table 36). Chile, with 17 percent of total seed import value, held second position in 1992, and Netherlands was third with 9 percent, followed by Japan with 6 percent.

Table 35--U.S. exports of seeds for planting; region and country share by value 1/

Region/country	1988	1989	1990	1991	1992
North and Central America:					
Canada	8.3	6.2	10.2	9.9	11.3
Mexico	12.6	25.4	14.4	13.0	17.8
Others	2.1	1.8	1.8	1.5	1.6
Total	23.0	33.4	26.3	24.4	30.7
South America:					
Brazil	1.2	0.6	0.5	0.5	0.5
Argentina	3.0	2.0	1.7	1.4	3.0
Chile	0.8	0.6	0.6	0.6	0.6
Colombia	1.1	0.6	0.5	0.6	0.6
Venezuela	3.3	0.6	0.4	0.6	0.4
Others	1.5	1.4	0.5	0.5	0.5
Total	10.8	5.9	4.3	4.1	5.6
Western Europe:					
United Kingdom	2.9	2.6	1.9	1.7	1.7
Netherlands	4.4	4.2	4.9	6.0	4.4
France	4.5	3.7	7.3	7.1	6.3
Germany	1.4	1.3	1.7	3.0	1.9
Spain	4.4	2.9	3.4	2.5	2.4
Italy	12.4	11.2	16.7	15.9	14.8
Greece	1.8	1.0	1.4	2.0	1.3
Others	3.1	2.5	3.1	3.5	3.4
Total	34.9	29.4	40.5	41.7	36.1
FSU 2/ and Eastern Europe					
Hungary	0.4	0.3	0.6	1.2	0.0
Romania	0.6	0.3	0.8	1.5	0.5
FSU	0.1	0.0	0.6	0.8	0.1
Yugoslavia				1.5	0.0
Others	0.8	0.4	0.0	0.2	0.9
Total	2.0	1.0	2.0	5.1	1.6
Asia:					
Turkey	1.0	1.5	1.0	0.6	0.9
Iraq	2.3	1.2	0.4	0.0	0.0
Saudi Arabia	4.2	10.4	10.0	9.3	7.9
Japan	11.8	8.9	7.7	7.0	8.1
South Korea	1.0	0.7	0.6	0.7	0.9
Others	4.2	3.3	2.9	3.3	3.8
Total	24.4	26.0	22.6	20.9	21.7
Africa:					
South Africa	1.1	1.2	0.9	1.0	0.8
Egypt	0.8	0.8	0.4	0.4	0.5
Others	1.0	0.8	1.4	1.1	1.6
Total	2.9	2.7	2.7	2.5	2.9
Oceania:					
Australia	1.7	1.2	1.2	1.1	1.2
New Zealand	0.3	0.3	0.2	0.2	0.2
Others	0.0	0.0	0.1	0.0	0.0
Total	2.0	1.6	1.5	1.3	1.4
Total	100.0	100.0	100.0	100.0	100.0

1/ Totals may not add due to rounding.
2/ Former Soviet Union.

Table 36--U.S. imports of seeds for planting; region and country share by value 1/

Region/country	1988	1989	1990	1991	1992
North and Central America:					
Canada	30.4	27.0	26.1	24.9	25.4
Mexico	2.1	3.0	3.4	3.8	3.2
Guatemala	2.4	2.3	2.7	2.5	3.8
Costa Rica	0.7	0.9	1.3	0.1	0.1
Others	0.1	0.0	0.0	0.1	0.0
Total	35.8	33.2	33.4	31.4	32.6
South America:					
Chile	6.8	13.3	11.2	10.7	17.2
Argentina	0.7	4.0	1.0	0.7	3.6
Others	0.8	0.4	0.1	0.3	0.4
Total	8.3	17.7	12.3	11.7	21.2
Western Europe:					
Denmark	1.9	1.5	1.4	1.2	1.7
United Kingdom	0.6	0.5	0.8	0.5	0.4
Netherlands	9.2	8.9	9.3	10.7	8.7
France	1.0	1.3	1.4	1.8	1.7
Germany	2.2	1.8	1.6	2.2	2.0
Italy	1.6	1.0	1.0	1.2	1.2
Others	0.3	1.4	0.1	0.5	0.5
Total	16.8	16.3	15.7	18.0	16.2
FSU 2/ and Eastern Europe:					
Hungary	1.2	3.1	0.7	0.1	0.4
Others	0.1	0.1	0.1	0.1	0.1
Total	1.3	3.1	0.7	0.1	0.5
Asia:					
India	7.5	3.5	3.1	5.2	2.7
Thailand	1.6	2.8	5.4	5.3	4.0
Taiwan	4.5	6.3	4.8	3.5	3.6
Japan	6.4	6.9	7.6	7.8	6.2
China(Mainland)	2.4	4.0	6.8	9.0	5.5
Others	2.0	1.5	2.9	0.5	0.4
Total	24.5	25.0	30.5	31.3	22.4
Africa:					
Ethopia	3.3	0.1	0.1	0.1	0.0
South Africa	0.5	0.0	0.0	0.0	0.5
Others	0.0	0.6	0.8	1.2	0.6
Total	3.8	0.7	0.9	1.3	1.1
Oceania:					
Australia	1.8	1.6	2.2	1.9	2.0
New Zealand	5.6	2.4	4.2	3.5	2.5
Total	7.4	4.0	6.4	5.5	4.5
Total	100.0	100.0	100.0	100.0	100.0

1/ Totals may not add due to rounding.
2/ Former Soviet Union.

Pesticide Prices Rise Again

Herbicide prices were up 1.9 percent and insecticide prices 7.7 percent in 1993, following increases of 2.4 and 4.8 percent in 1992.

Prices

Herbicide and insecticide prices have generally risen over the past 3 years (table 37). Pesticide manufacturers increased expenditures to research and develop new products and to develop additional data to reregister older products. In addition, many pesticide manufacturers have embarked on expensive biotechnology research. Dealer costs also have risen, especially for liability insurance.

Average farm-level herbicide prices rose 1.9 percent between 1992 and 1993, after a 2.4 percent gain in 1992. A major small grain herbicide, 2,4-D showed the greatest increase -- 9.2 percent. Atrazine, a major corn and grain sorghum herbicide, was second at 3.4 percent.

Farm-level insecticide prices are up 7.7 percent, compared with a rise of 4.8 percent last year. The price of methyl parathion (used extensively in cotton production for boll weevil control) is up 12.7 percent in 1993, following a 14 percent increase in 1992. The mild winter of 1992-93 increased in boll weevil pressure. Therefore, growers stocked up on methyl parathion; tightening supplies and increasing price.

Table 37--April farm pesticide prices 1/

Pesticides	1991	1992	1993	Change 92-93
	Dollars per pound 2/			Percent
Herbicides:				
Alachlor	6.15	6.35	6.45	1.6
Atrazine	3.25	3.48	3.60	3.4
Butylate	3.34	3.10	2.88	-7.1
Cyanazine	5.65	5.83	5.95	2.1
Metolachlor	7.49	7.69	7.79	1.3
Trifluralin	7.50	8.00	8.08	1.0
2,4-D	2.83	2.93	3.20	9.2
Composite 3/	5.04	5.16	5.26	1.9
Insecticides:				
Carbaryl	4.44	4.95	5.36	8.3
Carbofuran	10.39	10.84	12.20	12.5
Chlorpyrifos	10.65	11.30	12.03	6.5
Fonofos	10.30	10.20	10.75	5.4
Methyl parathion 4/	4.15	4.74	5.34	12.7
Phorate	7.78	8.06	8.80	9.2
Pyrethroids 5/	61.25	62.50	64.17	4.0
Terbufos	11.28	11.28	11.87	5.2
Composite 3/	12.33	12.92	13.91	7.7

1/ Derived from the April survey of farm supply dealers conducted by the NASS, USDA. 2/ Active ingredients. 3/ Includes above materials and other major materials but not products registered in the last 2 to 3 years. 4/ Supplied by Fred Cooke, Mississippi Agricultural Experiment Station. 5/ Average of fenvalerate and permethrin prices based on 2.4 pounds active ingredient per gallon.

Pesticide Use on 1992 Fall Potatoes

Fall potatoes are grown across the northern United States, from Maine to Washington. Herbicides were applied to 82 percent of the fall potato acreage in the 11 surveyed States (table 38). However, in Minnesota and North Dakota, where rainfall is low, only 63 and 42 percent of the acreage is treated with herbicides. Insecticide use was fairly uniform across all States (table 39). The proportion of acreage treated with fungicides was highest in the humid East and lowest in the more arid West (table 40).

Herbicides were applied only once on 59 percent of the fall potato acreage, and twice on 17 percent. The number of insecticide treatments averaged 2.3, ranging from 1.4-1.5 in Idaho and Colorado to 4.25 in New York and Pennsylvania. Fungicide treatments were highest in Maine at 7.8, followed by Wisconsin at 5.8.

Herbicides

Metribuzin was the most commonly used herbicide in fall potato production (table 38). It was either used alone or in combination with other herbicides to broaden the weed control spectrum. Metribuzin requires moisture shortly after treatment to be effective. A large share of the fall potatoes in the Pacific Northwest is treated with metribuzin because most of the crop is irrigated. Metribuzin, generally applied after planting but before potatoes emerge, controls such weeds as foxtail, ragweed, pigweed, and mustard.

EPTC was the second most commonly used herbicide. It is a selective herbicide that can be applied preplant or after planting prior to weed germination. It controls pigweed, foxtail, and wild oats. EPTC must be incorporated into the soil because it is readily lost by volatilization. It is most effective where rainfall is low.

Insecticides

Colorado potato beetles, aphids, and leafhoppers constitute the major insect problems in potato production. The Colorado potato beetle has developed some resistance to a number of organophosphorus insecticides, and to some of the newer synthetic pyrethroids.

The most commonly used insecticides across all States are esfenvalerate, methamidophos, and phorate (table 39). Carbofuran was used extensively in Minnesota and North Dakota. Carbofuran, a systemic, is generally applied at planting for flea beetle and early-season Colorado potato beetle control.

Table 38--Selected herbicides used in fall potato production, 1992 1/

Item	CO	ID	ME	MI	MN	NY 2/	ND	OR	PA	WA	WI	Area
1,000 acres planted	67	380	81	37	71	21	145	45	20	125	66	1058
1,000 acres treated with herbicides	50	362	80	26	45	18	61	39	15	103	62	862
Percent of planted acres treated:	76	95	99	70	63	84	42	87	77	82	94	82
With 1 treatment	63	63	93	42	51	26	36	54	46	63	71	59
With 2 treatments	13	26	5	16	12	30	3	23	26	13	14	17
With 3 treatments	nr	5	1	12	nr	28	2	9	5	6	8	5
With 4 treatments	nr	1	nr	nr	nr	nr	1	1	nr	nr	1	*
Average times applied	1.16	1.41	1.06	1.56	1.14	2.03	1.26	1.51	1.46	1.29	1.36	1.34
1,000 acre-treatments 3/	58	509	86	40	51	36	76	59	23	133	85	1156
Acre-treatments by active ingredient: 4/												
Single materials--												
EPTC	14	19	1	2	17	nr	4	20	4	15	1	13
Glyphosate	nr	*	nr	6	1	10	6	2	9	1	4	2
Linuron	2	nr	21	20	nr	15	nr	nr	4	nr	6	3
Metolachlor	nr	1	2	4	9	25	12	2	5	5	5	4
Metribuzin	21	53	72	30	15	23	6	28	18	41	51	43
Pendimethalin	nr	5	nr	nr	18	10	8	2	nr	3	2	5
Sethoxydin	5	*	3	8	11	3	8	1	nr	nr	4	2
Trifluralin	nr	*	nr	nr	3	nr	29	*	nr	4	nr	3
Other	nr	nr	1	1	nr	nr	nr	1	nr	nr	1	*
Combination mixes--												
Metolachlor + linuron	nr	nr	nr	20	nr	3	nr	nr	8	nr	nr	1
Metribuzin + EPTC	49	8	nr	nr	nr	nr	2	16	nr	4	nr	7
Metribuzin + metolachlor	7	1	1	4	12	12	nr	nr	48	nr	8	4
Metribuzin + pendimethalin	2	4	nr	nr	13	nr	14	9	2	17	12	7
Pendimethalin + EPTC	nr	2	nr	nr	nr	nr	nr	4	nr	5	nr	2
Trifluralin + EPTC	nr	2	nr	nr	nr	nr	nr	3	nr	1	nr	1
Other	nr	3	1	5	nr	nr	10	12	nr	4	7	4
Total	100	100	100	100	100	100	100	100	100	100	100	100

nr = None reported. * = Less than 1 percent.
1/ Preliminary. 2/ Excludes Long Island. 3/ Acres treated x times applied. 4/ Spot treatments not included.

Table 39--Selected insecticides used in fall potato production, 1992 1/

Item	CO	ID	ME	MI	MN	NY 2/	ND	OR	PA	WA	WI	Area
1,000 acres planted	67	380	81	37	71	21	145	45	20	125	66	1058
1,000 acres treated with insecticides	50	322	78	36	71	20	139	39	20	113	65	953
Percent of planted acres treated:	76	85	96	97	99	95	96	87	99	90	98	90
With 1 treatment	52	61	37	9	23	0	27	17	10	16	28	38
With 2 treatments	20	20	29	16	53	28	23	16	11	13	30	23
With 3 treatments	0	3	12	22	19	14	31	9	18	19	28	13
With 4 treatments	0	1	9	22	2	12	12	19	29	21	5	8
With 5 treatments	0	0	4	22	1	14	3	21	2	12	4	5
With 6 or more	4	0	5	6	1	27	0	5	29	9	3	3
Average times applied 3/	1.54	1.36	2.49	3.55	2.11	4.27	2.39	3.37	4.24	3.39	2.46	2.27
1,000 acre-treatments	77	439	194	128	150	85	332	132	84	383	159	2163
Acre-treatments by active ingredient: 4/ 5/												
Single materials--												
Azinphos-methyl	nr	10	13	4	8	4	7	3	5	3	1	6
Carbofuran	2	2	*	*	29	nr	53	1	2	2	1	11
Disulfoton	4	3	5	nr	nr	3	nr	6	nr	9	4	4
Endosulfan	26	4	11	8	7	10	8	0	2	*	20	7
Esvenvalerate	44	13	20	2	21	17	6	1	8	3	22	12
Ethoprop	nr	13	1	2	nr	1	nr	5	1	3	*	4
Methamidphos	4	6	27	0	6	16	10	35	9	32	7	16
Permethrin	5	6	2	2	nr	5	nr	8	3	5	22	5
Phorate	nr	36	nr	5	13	1	10	12	6	12	7	14
Phosphamidon	nr	nr	nr	nr	*	1	4	nr	nr	nr	nr	1
Other	12	5	14	23	8	26	1	7	28	16	10	11
All combination mixes	4	3	9	47	4	18	1	23	36	14	4	11
Total	100	100	100	100	100	100	100	100	100	100	100	100

* = Less than 1 percent. nr = None reported.
1/ Preliminary. 2/ Excludes Long Island. 3/ Acres treated x times applied. 4/ Spot treatments not included.
5/ Data were not tabulated to reveal insecticide-fungicide combination mixes.

Fungicides

Mancozeb, chlorothalonil, and maneb are the most commonly used fungicides in fall potato production (table 40). Early and late blight are the two most serious diseases.

Early blight kills the potato vine, reducing the food supply available for tuber production in the hill. Late blight kills the vine, and can also infect developed tubers, making them vulnerable to decay in storage. The disease organism is harbored in volunteer potato plants and in decaying vines and tubers left in the field. The disease organism contaminates the potato plant when rain splashes infected soil particles onto the foliage.

Mancozeb, maneb, and chlorothalonil are protective fungicides in that they must kill the disease organism before it invades the foliage. This explains the large number of fungicide treatments in high rainfall areas.

Table 40--Selected fungicides used in fall potato production, 1992 1/

Item	CO	ID	ME	MI	MN	NY 2/	ND	OR	PA	WA	WI	Area
1,000 acres planted	67	380	81	37	71	21	145	45	20	125	66	1058
1,000 acres treated with fungicides	65	147	80	30	60	19	136	36	19	107	62	761
Percent of planted acres treated:	98	39	99	82	85	91	94	80	93	86	94	72
With 1 treatment	18	21	9	17	19	21	32	19	5	16	1	19
With 2 treatments	29	9	4	15	43	5	16	23	10	26	6	16
With 3 treatments	31	7	3	8	12	5	32	10	6	19	17	14
With 4 treatments	16	1	nr	10	3	2	2	5	13	10	8	5
With 5 treatments	nr	1	1	6	nr	2	2	18	15	5	20	4
With 6 treatments	4	nr	9	10	nr	21	3	2	10	6	11	4
With 7 treatments	nr	nr	13	5	5	5	1	nr	16	1	9	3
With 8 treatments	nr	nr	19	10	3	7	6	3	10	2	6	4
With 9 treatments	nr	nr	11	1	nr	7	nr	nr	6	0	5	1
With 10 or more	nr	nr	30	nr	nr	16	nr	nr	2	1	11	2
Average times applied	2.63	1.47	7.81	4.1	2.47	5.56	2.72	2.91	5.37	2.97	5.80	3.48
1,000 acre-treatments 3/	171	216	629	124	149	106	370	105	100	319	361	2650
Acre-treatments by active ingredient: 4/ 5/												
Single materials--												
Chlorothalonil	13	44	13	2	21	3	12	26	4	18	11	15
Cooper hydroxide	19	10	*	1	nr	nr	nr	8	nr	2	2	3
Iprodione	nr	6	nr	1	nr	nr	1	13	nr	14	nr	3
Mancozeb	17	15	57	75	39	39	41	10	65	16	48	40
Maneb 6/	5	7	17	3	22	16	16	6	4	7	6	11
Metiram	nr	nr	nr	4	nr	nr	nr	nr	nr	4	nr	1
Triphenyltin hydroxide	36	nr	*	nr	5	nr	11	1	1	3	5	5
Other	nr	4	nr	1	nr	2	1	5	1	10	1	2
Combination mixes--												
Mancozeb + metalaxyl	nr	nr	9	7	nr	28	1	18	22	13	4	7
Mancozeb + triphenyltin hydroxide	4	nr	nr	nr	nr	nr	nr	nr	nr	nr	16	2
Maneb + triphenyltin	1	1	1	nr	11	nr	14	nr	nr	4	3	4
Other	6	12	2	6	2	12	4	12	3	10	5	6
Total	100	100	100	100	100	100	100	100	100	100	100	100

* = Less than 1 percent. nr = None reported.

1/ Preliminary. 2/ Excludes Long Island. 3/ Acres treated x times applied. 4/ Spot treatments not included. 5/ Data were not tabulated to reveal insecticide-fungicide combination mixes. 6/ Includes maneb + zinc

Herbicides on Winter Wheat

In 1993, herbicides were used on 43 percent of harvested winter wheat acreage in the surveyed States (table 41). In Idaho, Oregon, and Washington 91 to 98 percent of the winter wheat acreage was treated with herbicides in order to control annual broadleaf and grass weeds during mild periods in the winter. In Montana 98 percent of the winter wheat acreage was treated because winterkill thinned stands and invading weeds had to be controlled to prevent additional yield losses.

Chlorsulfuron and 2,4-D were the two most commonly used herbicides. Chlorsulfuron, registered in 1982, controls broadleaf and grass weeds and can be applied either pre- or postemergence. In contrast, 2,4-D controls only broadleaf weeds and is applied postemergence. Chlorsulfuron gained rapidly in popularity and by 1988 accounted for 49 percent of the winter wheat herbicide acre-treatments but by 1993 dropped to 15 percent. The reason is that weeds resistant to chlorsulfuron have been identified (kochia and Russian thistle) and farmers have been urged to rotate chlorsulfuron with other herbicides to slow resistance development in other weed species.

Table 41--Selected herbicides used in winter wheat production, 1993 1/

Item	CO	ID	IL	KS	MO	MT	NE	OH	OK	OR	SD	TX	WA	Area
1,000 acres harvested	2550	850	1550	11300	1400	2500	2100	1000	5500	860	1400	3700	2500	37210
1,000 acres treated with herbicides	562	830	327	4333	87	2445	798	152	1607	840	876	872	2268	15997
Percent of harvested acres treated:	22	98	21	38	6	98	38	15	29	98	63	24	91	43
With 1 treatment	21	81	21	36	6	87	33	15	29	71	54	23	75	39
With 2 or more	1	17	nr	2	nr	11	5	nr	nr	27	9	1	16	4
Average times applied	1.06	1.19	1.00	1.08	1.00	1.12	1.16	1.00	1.00	1.37	1.20	1.02	1.23	1.12
1,000 acre-treatments 2/	593	988	327	4688	87	2740	929	152	1607	1155	1050	889	2782	17987
Acre-treatments by active ingredient: 3/						Percent								
Single materials--														
2,4-D	16	11	6	15	4	8	43	60	10	4	21	40	21	17
Chlorsulfuron	nr	1	nr	40	nr	nr	nr	nr	48	nr	nr	10	nr	15
Dicamba	5	3	nr	1	nr	nr	9	24	2	1	nr	nr	nr	1
Glyphosate	nr	1	nr	6	nr	nr	2	nr	nr	nr	nr	nr	3	2
MCPA	nr	5	nr	1	nr	nr	nr	8	nr	6	nr	5	2	2
Metsulfuron	nr	1	nr	4	nr	2	7	nr	nr	nr	12	8	nr	3
Triasulfuron	5	nr	nr	1	nr	1	2	nr	5	4	nr	4	1	2
Other	nr	11	nr	nr	nr	7	5	nr	2	20	5	nr	12	5
Combination mixes--														
2,4-D + chlorsulfuron	nr	2	nr	5	nr	nr	nr	nr	2	nr	nr	nr	nr	1
2,4-D + dicamba	10	2	nr	3	nr	45	5	8	2	3	14	nr	1	10
2,4-D + glyphosate	5	1	nr	3	nr	nr	nr	nr	nr	2	7	3	nr	2
2,4-D + metsulfuron	10	nr	nr	5	nr	25	16	nr	2	nr	28	7	nr	8
2,4-D + triasulfuron	nr	nr	nr	2	nr	1	5	nr	nr	1	2	nr	5	2
Chlorsulfuron + metsulfuron	nr	nr	nr	4	nr	nr	nr	nr	27	5	nr	20	1	5
Thifensulfuron + tribenuron	11	4	89	nr	96	nr	nr	nr	nr	3	nr	2	5	4
Other 2-way mixes	16	16	nr	4	nr	3	7	nr	nr	5	12	nr	10	6
3-way mixes	21	21	6	8	nr	8	nr	nr	nr	34	nr	nr	30	12
4-way mixes	nr	23	nr	nr	nr	nr	nr	nr	nr	12	nr	nr	10	4
	100	100	100	100	100	100	100	100	100	100	100	100	100	100

nr - None reported.
1/ Preliminary. 2/ Acres treated x times applied. 3/ Spot treatments not included.

Nitrogen Fertilizer Application Timing Practices on 1992 U.S. Corn Acreage

Stan Daberkow and Harold Taylor [1]

Abstract: Applying nitrogen fertilizer during the corn growing season rather than in the fall generally minimizes the risk of environmental contamination from nitrate runoff and leaching. A 1992 survey indicated that about 25 percent of the 69 million corn acres treated with nitrogen was fertilized in the fall, while 33 percent received nitrogen after planting. Slightly more than half the corn acres received single nitrogen applications while the remainder received two or more applications. The most common multiple application combinations were at planting/after planting (9.8 million acres) and spring before planting/at planting (8.2 million acres). The survey results indicate an opportunity exists to address potential water quality problems by modifying the timing of nitrogen applications.

Keywords: Nitrogen fertilizer, application timing, corn

Introduction

Environmental, human health, economic, and regulatory issues continue to be associated with the use of fertilizers, especially nitrogen, in U.S. crop production. Nitrogen is a key input contributing to enhanced yields and farm revenue. However, evidence of nitrates in ground and surface water has led to ecological and human health concerns (5). Furthermore, nitrates that leach or runoff the land represent economic losses to farmers as well as to water consumers who must pay for nitrate removal. Because of these concerns, voluntary and regulatory measures are being proposed and, in some States, are already being implemented to encourage more efficient nitrogen fertilizer use. Many of these measures focus on reducing the risk of water contamination, while maintaining crop yields, by encouraging a better match between the timing of fertilizer applications and rapid crop uptake. Because corn is one of the most nitrogen- intensive crops and accounts for over 40 percent of all nitrogen fertilizer used in the United States, nutrient management programs are often targeted on this crop.

Background

The underlying premise of efforts to ensure efficient use and minimize loss is that nitrogen should be applied at or near the time it is needed by the crop. For corn, the most rapid uptake of nitrogen is midsummer. Fall fertilization of corn land, particularly before frost, is often targeted as being potentially harmful to water quality (1).

Rainfall during the fall, winter, and early spring months prior to crop uptake can lead to significant nitrate leaching or runoff. Conversely, nitrogen applied during the growing season is often promoted as a practice to reduce the risk of water contamination. The extent of potential nitrogen loss is also affected by soil type, climate, and terrain. Sloping, sandy fields subject to intensive rainfall or irrigation are the most susceptible to nitrate loss.

Both USDA and the Environmental Protection Agency have emphasized the importance of application timing in reducing the risks to water quality (3). Some States, such as Nebraska, have regulations that ban fall fertilization on environmentally sensitive cropland and encourage applications during the growing season (2).

While a single or split application during the growing season can minimize nitrogen losses to the environment, such a strategy may conflict with a producer's economic considerations (4, 6). For example, variation in precipitation patterns can unexpectedly reduce the time available for fertilizer applications during the growing season, thus increasing the risk of yield reduction. Also, fertilizer seasonal pricing patterns, on average, encourage fall rather than spring purchases (9). Furthermore, farmers' opportunity costs of labor may be much higher during the late spring and planting season than during the fall post-harvest time period. Different application costs by season and risk attitudes of producers are other important factors influencing application timing (6). Such economic considerations may lead to nitrogen applications during the fall or early spring, and for some producers, applying nitrogen over several application periods may be preferred.

Data

The corn Cropping Practices Survey sample is selected from an area frame sampling procedure. Each state is a stratum, except for Nebraska which has irrigated and non-irrigated districts (strata). Samples are selected within each stratum. Seventeen States were included in the corn sample with a total of 5,382 field-level observations that applied nitrogen. The States are Georgia, Illinois, Indiana,

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Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Carolina, Ohio, Pennsylvania, South Carolina, South Dakota, Texas, and Wisconsin. The survey area represents over 71 million acres of planted corn or about 90 percent of U.S. planted corn acreage.

The survey questionnaire includes questions on fertilizer use by field. The amount of nitrogen, phosphate, and potash for each application can be determined, as well as when the fertilizer was applied. The questionnaire requests the respondent to indicate, for each application, if the fertilizer was applied to the field in the fall before planting, in the spring before planting, at planting, or after planting. For this report, each of these time intervals is defined to be a fertilizer application period.

Application timing practices on USDA Cropping Practice Survey data for 1988 corn and 1990 corn, cotton, soybean, rice, and wheat have been reported in the literature (7, 8).

Table A-1-- Nitrogen use by application timing in corn production, 1992

	Application timing				
	Fall	Spring before planting	At planting	After planting	Total (annual)
Acres (mil.)	16.6	38.1	28.5	21.7	69.1 a/
Nitrogen applied (mil. lbs.)	1,597	4,232	694	2,374	8,898
Application rate (lbs./acre)	96	111	24	109	128

a/ Row does not sum to total because some acres are treated more than once. For application rates by season for 1988 and 1990 see sources 7 and 8.

In 1988 in the 10 major corn producing states, 23 percent of the acres planted to corn (12 million acres) were treated in the fall and received an average fall application of 100 pounds of nitrogen per acre. In 1990 in the same 10 states, 28 percent of the acres planted to corn (16 million acres) were treated in the fall and received an average of 102 pounds per acre.

Survey Results

In 1992, farmers used nitrogen on 97 percent of the 71.4 million acres of corn included in the Cropping Practices Survey. Of these 69 million corn acres, about 38 million (55 percent) were treated in the spring before planting and about 29 million (42 percent) were treated at planting (table A-1). In terms of nitrogen applied, 47 percent (4.2 billion pounds) was applied during the spring and only 8 percent (0.7 billion pounds) at planting. Much of the nitrogen applied at planting is a starter fertilizer that is typically used at very modest rates. For 1992, this rate was estimated at 24 pounds per acre.

The least used application season was the fall when nearly 25 percent (17 million acres) of all 1992 corn acres were treated. More importantly, over 1.6 billion pounds or about 800,000 tons (18 percent of the total) of nitrogen fertilizer were applied during the fall application period. At the other end of the timing continuum, about 22 million acres (32 percent) were treated with nitrogen after planting. However, only 27 percent (2.4 billion pounds) of the nitrogen was applied during this period when nitrogen uptake was most vigorous.

The survey data clearly indicate that many farmers split their nitrogen applications among two or more seasons (table A-2). While slightly more than half (36.4 million acres) of the corn acreage received nitrogen during one application period, about 33 million acres were treated during two or more periods. When corn producers applied nitrogen during more than one period, they most commonly chose either the spring/at planting combination (8.2 million

Table A-2-- Nitrogen use in corn production by application timing and period, 1992

		Nitrogen application timing							
Application period 1/	Acres treated	Annual total	Applications First	Second	Third	Annual total	Applications First	Second	Third
	million	Million pounds				Pounds per acre			
F only	7.3	1,006	1,006	NA	NA	138	138	NA	NA
Sb only	20.4	2,532	2,532	NA	NA	124	124	NA	NA
At only	4.9	214	214	NA	NA	44	44	NA	NA
Af only	3.8	450	450	NA	NA	118	118	NA	NA
F + Sb	3.4	512	137	375	NA	152	41	111	NA
F + At	2.7	365	305	60	NA	136	113	22	NA
F + Af	2.0	322	94	228	NA	158	46	112	NA
Sb + At	8.2	1,106	960	146	NA	134	117	18	NA
Sb + Af	3.5	537	182	355	NA	154	52	102	NA
At + Af	9.8	1,327	214	1113	NA	136	22	114	NA
F + Sb + At	0.5	84	21	56	7	171	43	115	14
F + Sb + Af	0.2	33	3	13	16	190	19	76	96
F + At + Af	0.5	91	31	10	50	185	63	21	102
Sb + At + Af	1.9	317	113	43	161	166	59	23	84
Total	69.1	8,898	NA	NA	NA	128	NA	NA	NA

NA - Not applicable.
1/ F - Fall; Sb - Spring before planting; At - At planting; and Af - After planting

acres) or the at planting/after planting combination (9.2 million acres). A modest 3 million corn acres received nitrogen during three application periods.

Annual nitrogen application rates tended to increase as the number of application periods rose (table A-3). While application rates are determined by a number of factors, especially those affecting yield, the survey data indicate that, all things being equal, application rates averaged 115 pounds per acre for corn receiving single period applications, compared with 144 per acre for acreage treated over several periods. If fall applications are excluded, these rates become 110 pounds per acre and 175 pounds, respectively.

About 7.3 million acres received nitrogen only in the fall, while another 9.3 million acres received nitrogen in the fall and during one or more other periods. These 16.6 million acres, which would be affected by policies or regulations that shift nitrogen application closer to plant uptake, have vastly different fall application rates. Fall only applications averaged 138 pounds per acre while fall plus other period applications averaged less than half that rate. The amount of fertilizer applied during the fall is clearly influenced by whether a producer intends to apply additional fertilizer during some succeeding time of the year.

Table A-3-- Corn acres treated, nitrogen applied, and application rate by single and multiple season application, 1992

Applications	Single application only	Multiple applications	Total
Fall application			
Acres (mil.)	7.3	9.3 2/	16.6
Nitrogen applied (mil. lbs.)	1,006	592 2/	1,598
Application rate (lbs./acre)	138	64 2/	96
Other applications 1/			
Acres (mil.)	29.1	23.4	52.5
Nitrogen applied (mil. lbs.)	3,196	4,104	7,300
Application rate (lbs./acre)	110	175	139
Total			
Acres (mil.)	36.4	32.7	69.1
Nitrogen applied (mil. lbs.)	4,202	4,696	8,898
Application rate (lbs./acre)	115	144	128

1/ Other application are spring before planting, at planting, and after planting. 2/ Fall plus other application periods.

At the other application timing extreme, about 3.8 million corn acres received nitrogen only after planting and another 17.9 million acres received nitrogen after planting and during one or more other application periods. Of these 17.9 million acres, 2.7 million were treated in both the fall and after planting. Acres receiving nitrogen only after planting had an application rate of 118 pounds per acre, compared with 107 pounds per acre when nitrogen was also applied during a previous application period.

Summary

Economic and environmental considerations associated with nitrogen fertilizer use are focusing greater attention on fertilizer application timing. Matching nitrogen application with plant uptake, which occurs in midsummer for corn, reduces the potential for environmental degradation. However, nitrogen application after planting can conflict with economic considerations, such as fertilizer prices, uncertainty with respect to when field operations can occur, risk attitudes, and opportunity costs of labor and management, which encourage farmers to apply fertilizer other times during the crop year or to split their applications over several periods. Fall fertilization, with its potential for nitrate leaching and runoff, is of particular concern, although the risks to water resources vary widely by soil, climate, and topography.

Nearly one-quarter of all corn acres receive nitrogen fertilizer during the fall prior to planting, and these applications account for one-fifth of the total nitrogen applied to corn. Thus, the survey results indicate that water quality could be improved by modifying nitrogen application timing. However, the magnitude of water quality changes will depend on the leaching and runoff potential of fields receiving fall applications. Further analysis is needed to assess how such a shift in timing would alter producers' costs, net returns, and risks. Nevertheless, the survey indicates that a significant number of producers already use a variety of other application timing strategies that do not require fall fertilization.

References

1. Blackmer, A. M., "Losses and Transport of Nitrogen from Soil" in *Rural Groundwater Combination*, ed. by F. D'nitri and L. Wolfson, Lewis Publishers, Chelsea, MI, 1987.

2. Central Platte Natural Resource District, "Groundwater Quality Management Program: Groundwater Quality Improvement for the Central Platte Valley," Grand Island, NE, July 1993.

3. Dicks, M., P. Norris, G. Cuperus, J. Jones, and J. Duan, "Analysis of the 1990 Integrated Crop Management Practice," Circular E-925, Oklahoma State University, Stillwater, OK, 1992.

4. Feinerman, E., E. Choi, and S. Johnson, "Uncertainty and Split Nitrogen Application in Corn Production," *American Journal of Agricultural Economics*, Vol. 72, Nov. 1990.

5. Freshwater Foundation, "Nitrates and Groundwater: A Public Health Concern," Navarre, MN, 1988.

6. Huang, W., L. Hansen, and N. Uri, "The Timing of Nitrogen Fertilizer Application: the Case of Cotton Production in the U.S.," *Applied Mathematical Modelling*, Vol. 17, Butterworth-Heineman Publishers, Feb. 1993.

7. Taylor, Harold H. "Fertilizer Application Timing," *Agricultural Resources: Inputs Situation and Outlook Report.* Economic Research Service. AR-24, October 1991, pp. 30-38.

8. Taylor, Harold H. and Harry Vroomen. "Timing of Fertilizer Applications," *Agricultural Resources: Inputs Situation and Outlook Report.* Economic Research Service. AR-15, August 1989, pp. 40-45.

9. Vroomen, Harry and Harold Taylor, "Fertilizer Price and Use Statistics, 1960-91," Statistical Bulletin No. 842, Economic Research Service, USDA, November 1992.

Analysis of Pesticide Use by Tillage System in 1990, 1991, and 1992 Corn and Soybeans

Len Bull, Herman Delvo, Carmen Sandretto, and Bill Lindamood [1]

Abstract: This study examines the relationship between pesticide use and tillage systems in production of corn and soybeans in 1990, 1991, and 1992. Little difference between tillage systems was observed in the percentage of acres treated or in the number of herbicide treatments. Average pounds of herbicide active ingredient applied did not exhibit a consistent pattern across tillage systems over the years. About 40-50 percent of the herbicide acre-treatments were combination mixes of more than one ingredient. The exception was no-till, where about 50-60 percent of the acre-treatments were combination mixes. Corn insecticide applications were not significantly different between tillage systems, although no-till acreage reported lower use for each year.

Keywords: Pesticides, tillage systems, herbicide use, acre-treatments, pesticide use patterns

National agricultural policy is currently focusing on the potential risk of pesticides used in crop production and how their use may affect water quality and food safety. The conservation compliance provisions of the 1985 Food Security Act (FSA) and the Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA) require farmers to implement conservation practices on highly erodible land (HEL) by 1995 or become ineligible for farm program benefits. The United States Department of Agriculture (USDA) has developed soil conservation plans for 141 million acres of highly erodible U. S. cropland. These plans include crop residue management as part of the recommended treatment on about 75 percent of the 110 million HEL acres planted to crops.

Tillage operations are used to destroy weeds and habitat favorable to pests. Pesticides are commonly used with all tillage systems to control weeds, insects, and diseases. However, because crop residue management (CRM) systems normally involve fewer tillage operations, the perception is that these systems require significantly greater quantities of chemicals. Increased biological activity associated with CRM systems is presumed to be a negative factor that leads to increased fertilizer immobilization or loss, insect activity, and disease problems. In addition, decreased tillage is assumed to lead to greater weed problems. Therefore, the conclusion is that greater inputs of fertilizers and pesticides are required (*11*). If true, a potential conflict may exist between conservation compliance plans that specify the use of CRM systems to control soil erosion and water quality objectives that advocate reduced pesticide use. Reevaluation of these policies and objectives would be the result of such a conflict.

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This study examines the relationship between tillage systems and pesticide use on corn and soybeans for the major producing States. The data was obtained from the Economic Research Service Cropping Practice Surveys for 1990, 1991, and 1992. These surveys collected information on tillage systems, pesticide applications, pesticide quantities, and other production inputs covering about 80 percent of production acreage. Analyses of these data have implications for evaluating the impact of public policies designed to protect the food supply and to improve environmental quality. These include policies resulting from conservation compliance, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the Clean Water Act of 1972, and the Water Quality Act of 1987.

Definitions and Methodology

Tillage systems are defined in terms of the extent of soil disturbance and the management of crop residues. Tillage system designations are based on the estimated residue remaining immediately after planting (*8*, *9*). Mechanical cultivations for after-planting weed control are not included when defining tillage systems. Residue levels are obtained by estimating the residue remaining from the previous crop and reducing this residue level by the incorporation rate associated with each tillage and planting implement used.

The five tillage systems defined for this analysis are mulch-till, no-till, ridge-till, conventional tillage with the moldboard plow, and conventional tillage without the moldboard plow. Mulch-till, no-till, and ridge-till are identified as conservation tillage systems. A conservation tillage system is defined as one that leaves 30 percent or more of the soil surface covered with crop residue after the planting operation. Tillage methods which leave less than 30 percent surface coverage are identified as conventional tillage and are divided into systems that use a moldboard plow and those that do not.

Tillage Systems, Crop Residue Management, and Water Quality--Surface Water

Proper management of crop residue is an effective technique to reduce soil erosion and water runoff, improve soil tilth and organic matter, and increase moisture retention. Tillage practices that leave substantial amounts of crop residue evenly distributed over the soil surface are a primary defense against the impact of rainfall kinetic energy which contributes to sealing of the soil surface and reducing infiltration rates, thereby, increasing surface runoff. In addition, the filtering action of the increased organic matter associated with higher levels of crop residue results in cleaner runoff with less sediment and sediment-adsorbed chemical (fertilizers and pesticides) losses (*28*).

More crop residue on the surface also increases interception of chemicals and facilitates breakdown into harmless components through action of microorganisms contained in the slowly decaying organic residue and degradation due to exposure to air and sunlight (*11, 23, 35*). Thus, under normal conditions, the presence of increased crop residue usually reduces the volume of contaminants associated with runoff to surface waters by constraining sediment losses and enhancing infiltration (*13*).

Tillage Systems, Crop Residue Management, and Water Quality--Ground Water

Greater infiltration resulting from the surface residue increases soil moisture but raises concerns about the potential leaching of dissolved chemicals into shallow ground water (*2, 36*).

Concerns about ground water quality arise from the knowledge that (1) post-emergence herbicides are relatively more important in no-till systems; (2) on many soils in humid regions, surface water runoff is reduced and infiltration is enhanced with no-till due to increased organic matter and more macropores near the soil surface; and (3) no-till permits continuous row-crop production on slopes that require rotational cropping when clean tillage and cultivation are used for weed control (*12, 14*).

Analyses of chemical properties have shown that post-emergence and burndown herbicides are generally less mobile and less persistent, and, therefore, less likely to migrate from their target during water infiltration (*37*).

Macropores, such as, earthworm burrows, large root tunnels, and/or large expansion/contraction cracks, create the potential for preferential flow paths to deliver water and surface-applied chemicals rapidly through the top layers of the soil profile. The lack of disruptive tillage allows them to persist. However, macropores are not direct conduits from the soil surface to the groundwater aquifer but instead rarely extend to depths greater than 1 meter in many soils *(12)* . Since macropores are essentially dead-end tubes within the root zone, water and chemicals infiltrating through them are held where microorganism activity can enhance breakdown.

The increased volume of infiltration normally dilutes the concentration level of contaminants in the percolate to ground water (*33*). Studies on reduced soil compaction and improved internal field drainage by subsurface drainage tile indicate that field practices that increase water infiltration can reduce herbicide runoff (*4, 7*). The timing, route, and volume of infiltrating water are very important relative to chemical losses in surface runoff or subsurface drainage (*2*).

The crop grown the previous year can have a great influence on successful use of conservation tillage, especially no-till. The kind, amount, and distribution of previous crop residue can influence soil temperature and allelopathy. "Allelopathy," or "autotoxicity," refers to the reduced germination and lack of early growth that sometimes result from placing seed under or near decaying residue from the same crop or a closely related species *(19)*. Thus, no-till and mulch-till production are more likely to be successful with crop rotation than with continuous cropping. Ridge-till is suited only to row crops, and therefore, is often used with continuous cropping.

Thus, under normal climatic and hydrologic conditions, crop residue management systems (including mulch-till, ridge-till, and no-till in particular) are no more likely to degrade water quality than other tillage systems (*1, 2, 12, 14, 35*). In summary, there is decreased potential for surface water contamination with crop residue management systems and, under normal conditions, the potential for ground water contamination is no greater than for other tillage systems. Therefore, the conclusion is that changing to conservation tillage systems should cause a net decrease in total potential water degradation.

However, there is still a great deal of "conventional wisdom" which states: Since conservation tillage systems apply greater quantities of pesticides and increased residue reduces water runoff, infiltration will, therefore, result in degradation of the groundwater.

Study Objective

The objective of this study was to determine if there were significant differences in pesticide use between tillage systems. The hypothesis that farmers using conservation tillage systems did not apply a significantly different amount of pesticides than farmers using conventional tillage systems was investigated. The percent of acres treated, number of pesticide applications, and quantity of active ingredient applied were analyzed in the study. If pesticide levels are not greatly different, some cost savings, from decreased labor and machinery costs, of switching to conservation tillage systems should be realized as increased net returns.

Significance tests (difference between two means) comparing each tillage system with each other system in the same year were carried out using the "t" statistic at the 5 percent level (95 percent level of confidence). This test utilized a program, PC CARP, to compute the weighted "t" tests for survey data. This program was developed at the Iowa State University Statistical Laboratory (*16*).

Corn – Herbicides

Because conservation tillage systems, particularly no-till and ridge-till, reduce the options for mechanical weed control prior to planting, herbicide treatments might be expected to substitute for tillage activities. Survey results, however, indicate little difference among tillage systems in the percentage of acres treated with herbicides (table B1).

The average number of applications (treatments) with no-till was not significantly different than for other tillage systems, except for being greater than conventional tillage with the plow in 1991 and less than mulch-till in 1992.

In addition, there was very little difference in the pounds of active ingredient (a.i.) applied (table B1). No-till levels were not significantly different than any other tillage system in 1990. In 1991, no-till systems used significantly greater amounts of a.i. than conventional tillage systems. In 1992, no-till a.i. use was higher than conventional tillage with the plow and mulch-till but not significantly different than conventional tillage without the plow.

These results also indicate that the number of treatments does not appear to be a reasonable proxy for pounds of active ingredient applied.

Application rates for mulch tillage were sometimes higher and sometimes lower than the rates of other systems. These differences were often not significant.

Significantly lower application rates occur with ridge-till compared to the other systems. Ridge-till systems, 2 percent of the total acreage (*32*), use mechanical cultivations to kill weeds between the rows as they rebuild the ridges. Chemicals are often applied in bands along the rows at the same time, thus resulting in the application of about a third of the herbicide that would be used in broadcast applications. Using mechanical cultivations as a substitute for herbicide use and banding some herbicide applications tends to lower the average application rate per acre.

The lack of a consistent pattern in herbicide a.i. application rate per acre would indicate that the tillage system was probably not the principal reason for the differences. Other elements such as weather, soil type, tillage system experience, and inherent weed problems could be more influential factors. The relative impact of these factors may also vary from year to year.

One apparent difference between tillage systems is that combination mixes are used more with no-till systems. Herbicide can be applied as a single active ingredient or as combination mixes where two or more active ingredients are combined and applied in one trip over the field. Herbicide combinations broaden the spectrum of weed control and can be either premixed products, or individual products mixed in a spray tank before field application.

For most tillage systems, about 50 percent of the acreage treated with herbicides received a combination mix (table B1). For no-till, a greater proportion of acreage was treated with mixes (60 percent), and these mixes were often combinations of three or more chemicals. This increase is short-term and is due to a broader spectrum of weeds resulting from decreased tillage operations and no incorporation of preplant herbicides into the soil (*13*). Other factors may be an attempt to minimize trips over the field and the possibility that no-till operators mix chemicals to target specific weeds. Effective control often depends on spraying weeds at the right stage of growth, plant stress, etc. Consequently, different management skills are required to control weeds with no-till (*27*).

The pounds of a.i. per acre-treatment increase as more ingredients are combined. Acre-treatments are the number of acres treated, multiplied by the average number of applications during the growing season. Since no-till systems use more three-way and four-way combinations, one would expect an increase in the amount of a.i. per treated acre. The data reflect this, even though the higher level is not always statistically significant. Again, this indicates the impact of factors other than tillage systems.

A slight increase in the amount of a.i. per acre is also consistent with the finding that during the first 2 or 3 years with a no-till system, operators often use more herbicides (*25*). New users of no-till are indicated by the steady increase in no-till acreage from 1988 to 1992 (*31, 32*). However, once they become familiar with the no-till system and the weed seeds in the top few centimeters of the soil have been controlled, herbicide use declines to below that of the previous tillage system (*13, 25*).

With tillage, a portion of the weed seeds produced annually are incorporated into the soil and become dormant. In addition, some new seeds and some dormant from previous tillage are brought up into the germination zone near the surface where they are likely to germinate. This is an annual occurrence with tillage and provides a continual source of weed seeds (*26*).

Without tillage, dormant weed seeds are not brought up, but most of the seeds produced that year are near the surface and may germinate. This can cause an increased weed problem until these weeds can be controlled. Once this surface reservoir of weed seeds has been depleted and weed populations have been controlled, many long-term no-till practitioners say that the weed problem is limited to a few specific weed species and the level of herbicide use can be decreased, perhaps to only some spot treatments (*25*).

Thus, a reduction in tillage can have the effect of increasing the germination of newly produced weed seeds over the short term, resulting in the need for more combination mixes and/or more herbicides. On the other hand, the reservoir of dormant weed seeds resident in the soil is not transferred to the germination zone near the soil surface by tillage. Consequently, the weed problem may decrease after a few years, if fields are converted to conservation tillage and if effective weed control is practiced (*13*). In addition, crop residue mulches may help reduce weed seed germination. Therefore, the need for herbicides in future years is expected to decrease on no-tilled fields.

The type of a.i. did not show wide variation in incidence across tillage systems for corn (*10*). Atrazine, alachlor, cyanazine, and metolachlor were the most frequently used, either singly or in combination mixes. These four products accounted for over 80 percent of the total pounds of a.i. applied with each tillage system (*34*). EPTC was frequently used with conventional and mulch tillage but not with no-till because it must be incorporated into the soil or it is lost by volatilization.

Corn – Insecticides

The use of insecticides occurs much less often than herbicide use. The percent of planted acres treated with insecticides was consistently greater for ridge-till than the other systems (table B1). Much of the ridge-tilled corn follows corn, which increases the probability of damaging insects, particularly the corn rootworm larvae. In addition, row planting on ridges quite often occurs very near the same slot as previous plantings. Soil insects, such as corn rootworm larvae, remaining from the previous year will also be near this slot. This greater probability of proximity of the new crop and harmful insects may also contribute to the increased insecticide use with ridge tillage. The other tillage systems averaged around 30 percent treatment. No-till systems had lower insecticide use than the other systems in each year.

The number of treatments showed some variation, with ridge-till always higher. The variations were not statistically significant, possibly due to the small number of sample observations using insecticides.

The average pounds a.i. of insecticide per treated acre also were not significantly different between systems. However, a lower rate was consistently reported for no-till than for the other systems. Since a larger insect problem (requiring greater use of insecticides) is associated with continuous corn rotations, this lower rate may be illustrating the fact that no-till systems are normally better suited to the use of rotations than for continuous cropping (*19*).

Corn – Weed Control Cultivations

Since mechanical weed control cultivations do not enter into the definition of tillage systems, they may be used as a pest control alternative and can be a substitute for herbicides. However, these cultivations do have disadvantages. Cultivation interrupts the buildup of organic matter and the activity of earthworms and microorganisms. It also tends to "till" the soil which brings up dormant weed seeds and stirs up seeds near the surface. This activates germination of another "flush" of weeds.

Cultivation can also expand the perennial weed problem by spreading the rhizomes and tubers. In the long run this would tend to maintain a continuous weed problem *(25)*. Without soil tillage (a no-till system without mechanical cultivation), long run effects include a decreased weed problem and increased organic matter due to greater microorganism and earthworm activity.

The percentage of no-tilled acres that received mechanical weed control cultivations was much less than for other tillage systems (table B2). However, of the cultivated acres, the number of cultivations averaged about 1.2 to 1.5 for all tillage systems except for ridge-till (1.8). This may reflect increased weeds for the initial years of no-till and indicate that greater chemical use may not be the only alternative for controlling weeds. Ridge tillage systems normally use one to two mechanical cultivations during the season to maintain the ridges in addition to controlling weeds.

Soybean – Herbicides

Pesticides other than herbicides are not frequently applied to soybeans under any crop residue management system. Insecticides were applied to less than 3 percent of soybean acres across all tillage systems. Fungicide applications were made on less than 1 percent of the soybean acres. No analysis of the use of these other pesticides by tillage system was made.

Soybean acreage was broken into two regions for analysis because of wide differences in input usage and tillage systems. Within this analysis, the northern region consists of Illinois, Indiana, Iowa, Minnesota, Missouri, Nebraska, and Ohio. The southern region includes Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, and Tennessee.

As with corn, survey results indicate no consistent pattern in the differences among tillage systems in the soybean acres treated with herbicides (tables B3 and B5). Treated acres ranged from 94 to 100 percent in the northern area and from 78 to 98 percent in the southern area. There was some variation between years and between tillage systems. In the northern area, the percentage of treated acres tended to be lower with no-till than for other tillage systems.

The number of treatments (separate field operations) varies across years and tillage systems. The differences for some years and for certain tillage systems were sometimes significant. The average number of herbicide applications on treated acres ranged from 1.2 to 1.8 in both regions.

The level of a.i. per treated acre was higher for no-till, due to the increased number of treatments and the greater use of three-way and four-way combination mixes. However, these rates were not always significantly greater than for other systems. For example, no-till rates were not significantly different from conventional tillage with the moldboard plow in the northern area in 1991 and in the southern area in 1992.

As with corn, soybeans grown with mulch tillage sometimes used less and sometimes more herbicides per acre, but often not significantly different than for other tillage systems.

These results indicate that the tillage system was probably not the primary reason for these differences. Other factors such as weather, soil type, tillage system experience, and inherent weed problems could be more important determi-

nants. Yearly variation may also occur in the relative impact of these factors.

Unlike corn, the type of a.i. applied did vary across tillage systems in soybean production (*10*). Trifluralin was the most widely used active ingredient in both conventional tillage systems and mulch tillage. It had an average application rate of 0.87 pounds per acre. Trifluralin is applied preplant and incorporated into the soil with a tillage implement.

For no-till and ridge-till systems, no single active ingredient or combination mix was clearly dominant in the northern region before 1990. Since 1990, imazethapyr has become the most widely used a.i. with northern area no-till systems, at an average rate of 0.06 pounds per acre. Imazethapyr can be applied preplant incorporated, preemergence, or postemergence. It controls many broadleaf weeds and certain grasses.

In the southern region, the most commonly used ingredients with no-till were glyphosate and fluazifop, at average rates of 0.85 and 0.15 pounds per acre (*10*). Glyphosate is applied before the soybeans emerge to kill existing vegetation and fluazifop is a postemergence treatment.

The use of active ingredients with lower application rates explains the lower pounds of a.i. applied per acre-treatment for no-till as compared to conventional tillage with the moldboard plow. This is particularly true for the single ingredient and two-way combinations. For most years, a greater number of treatments pushed up the total pounds of a.i. per acre for the no-till system. However, in 1989, the number of treatments were not significantly different among any of the tillage systems (*10*).

While the average number of herbicide applications is similar for all tillage systems for soybeans, the use of combination mixes is more prevalent with no-till systems. About 50-70 percent of the herbicide acre-treatments in conventional and mulch tillage were applications of single active ingredients (tables B3 and B5). However, for no-till, less than 50 percent of the acre-treatments were single products.

Although combinations of two or more active ingredients are common in all tillage systems, no-till contained more with three or more ingredients. Increased herbicide combinations with no-till are due to a broader spectrum of weeds in the short run, resulting from decreased tillage operations and no incorporation of preplant herbicides into the soil (*13*). Other factors may include the attempt to minimize trips over the field and that no-till operators, more dependent on herbicides for weed control, target weed control efforts more effectively by using a.i. combinations.

Soybean – Weed Control Cultivations

About 75 percent of the soybean acreage was planted with a row planter, 76 percent in the northern area and 74 percent in the southern area. Acres planted with a row planter are called "wide-row" as opposed to those planted with a drill. Only the wide-row soybeans have the potential for mechanical cultivation. In the northern area, the majority of the no-till soybeans were planted with a drill (narrow-row), 60 to 80 percent (table B4). In the southern area, about the same percentage of the no-till soybeans were wide-row planted (table B6). Except for ridge-till, which is wide-row by definition, the soybeans with the other tillage systems were also about 60 to 80 percent wide-row for both areas.

Mechanical weed control cultivations, on the acres that were row planted and cultivated, averaged about 1.5 times for the northern area across all tillage systems, with ridge-till being higher in some years (table B4). The southern area averaged about 2.0 times for all tillage systems (table B6). A smaller percentage of no-tilled acres were cultivated than for other tillage systems.

Tillage Systems, Chemical Use, and Water Quality

The behavior of chemicals in the environment is determined by their interrelationship with soil, plants, and water. The movement of chemicals from the point of application to ground or surface waters depends on a complex interaction between a variety of site specific factors. These factors range from the climate and the hydrologic, geologic, and topographic characteristics of the land surface to the inherent characteristics of the soils and the applied chemical materials (*28, 35*). Pesticide materials that are highly mobile and long lived in the environment are less desirable than those that are short lived and immobile because they adhere tightly to the targeted material or the soil.

The fate of applied chemicals is particularly dependent on the respective properties of the active ingredients, such as their adsorption, persistence, solubility, and volatility characteristics (*11, 13, 37*). Chemicals with high water solubility and low adsorption characteristics are highly mobile and possess the potential for loss through surface runoff or subsurface drainage (leachate).

Pesticides that are strongly sorbed (adsorbed or absorbed) by soil, sediment particles, or organic matter are protected from chemical or biological degradation and volatilization while sorbed to these materials. Pesticides that are tightly held will not readily leach to groundwater and will be found in surface water runoff only under erosive conditions where the particles they are attached to are washed off the fields. The soil sorption property is a major factor affecting the pollution potential of a particular pesticide (*37, 38*).

The behavior of chemical compounds in the environment is also influenced by the application method. For example, whether a pesticide is applied to foliage or the soil, or incorporated into the soil makes a big difference in how easily the application deposits can be dislodged by rain, and thus be leached into the soil or transported in surface runoff. Soil incorporation physically lowers the susceptibility of a pesticide to volatilization and thereby increases its persistence (*37*).

Pre-emergence herbicides are generally tilled into the soil where they must be mobile and persistent for a sufficient period of time to make contact with and destroy weed seedlings throughout the expected weed germination period. These enhanced mobility and persistence properties also facilitate the migration of pre-emergence chemicals in the environment through surface water runoff or percolation to ground water.

Post-emergence and burndown herbicides are generally less mobile and less persistent, and, therefore, less likely to migrate from their target. Pesticides applied to plant foliage, for instance, leave pesticide deposits that are highly vulnerable to photolysis and other degradation processes that reduce persistence and the potential for water pollution (*37*). For example, glyphosate and paraquat, although highly soluble, are strongly adsorbed and rapidly converted to relatively harmless degradation products that reduce their potential for contaminating ground water.

The difference in chemical properties between pre-emergence and post-emergence or burndown herbicides is important when considering the environmental impact of herbicide use between tillage systems. Tillage systems that employ herbicides with lower mobility and shorter persistence are preferable from a water quality standpoint to tillage systems that require herbicides with greater mobility and longer persistence (*37*).

Therefore, when considering pesticide application rates between tillage systems, to make a statement such as "two pounds a.i. (herbicide x) is more harmful to the environment that 1.5 pounds a.i. (herbicide z)" may be totally untrue. The inherent toxicity of the active ingredients and their degradation products to nontarget species, and their mobility and persistence in soil and water determine their relative impact on the environment. However, a specific pesticide can be converted by environmental processes including hydrolysis, photolysis, and other processes into an important degradation product with different chemical properties (*37*). The real comparison that needs to be examined is the type of a.i. by tillage system, not the total amount of active ingredients.

Tillage systems employing newer pesticides that are highly toxic to targeted species but are used at much lower rates may be more environmentally desirable. Since for a given chemical, the amount of active ingredient being dissipated into the environment is generally proportionate to the amount applied, lower application rates translate into reduced exposure of nontarget species to the side effects of these chemicals (*37*).

Recent research indicates that under normal climatic and hydrologic conditions, crop residue management systems (including mulch-till, ridge-till, and no-till in particular) are no more likely to degrade water quality than other tillage systems (*1, 2, 12, 14, 35*). Several field studies (*3, 17, 20*) conducted on small watersheds under natural rainfall on highly erodible land (14 percent slope) have shown that no-till reduces soil erosion by more than 90 percent compared with moldboard plow tillage. Water runoff under field conditions was more variable depending on the frequency and intensity of rainfall events but averaged about 30 percent of the amounts from moldboard-plowed fields (*3, 17, 20, 29*). Average herbicide runoff losses from treated fields with no-till systems for all products and all years were also about 30 percent of the runoff levels from moldboard-plowed fields (*14*).

Summary and Conclusions

The percentage of acres treated with herbicides, the number of applications, and the pounds of a.i. applied per acre did not indicate consistent differences between tillage systems in 1990, 1991, and 1992 corn and soybean production. Even though there were some statistically significant differences between tillage systems, these differences were not consistent across all years, tillage systems, or for all crops.

Other studies have also shown that, while conservation tillage systems can change weed and insect problems and the kinds of herbicides and insecticides used, total use of herbicide and insecticide has not changed greatly when farmers convert to conservation tillage (*13, 14, 22*). Analysis of pesticide quantities by tillage system should conclude that appropriate conservation tillage systems should not increase the risk of undesirable impacts from pesticides on human health and aquatic life (*14*).

Therefore, these results suggest that it is not appropriate to state that conservation tillage systems, or a no-till system in particular, uses more herbicides than conventional tillage systems. This might be true for a specific crop for a particular year, but not consistently. Crop rotation, moisture availability and timing, nonchemical pest management practices, and other factors influencing pest populations probably have greater impact upon pesticide use in annual crop production than just the tillage system. The perceived negative aspects of conservation tillage systems, such as potentially higher pesticide and nitrogen use and greater leaching of chemicals because of increased infiltration and macropores, appear to be unfounded (*6*). These results suggest that the use of conservation tillage systems should decrease the potential for water degradation.

It is also inappropriate to compare pounds of active ingredient between tillage systems and conclude that more is worse for water quality. Other a.i. properties, such as toxicity, leachability, and persistence, have direct impact upon water quality and these properties can be considerably different between active ingredients. This is particularly true for soybeans where there is wide variation in the active ingredients applied with no-till systems compared to the other systems. Therefore, further study of pesticide use by tillage system and its relationship to water quality should focus on a.i. type and the relative impact of a.i. properties on water quality.

The potential exists for problems with a broader spectrum of weeds with no-till and ridge-till, at least for the first few years after converting to these systems. Consequently, no-till and ridge-till systems for both crops often make greater use of combination mixes than other tillage systems in a likely response to these potential problems. Thus, there

could be a short-term conflict between conservation compliance plans specifying increased use of conservation tillage systems and water quality objectives to reduce pesticide use. However, indications are that these objectives become compatible after a few years.

References

1. Baker, J. L. "Agricultural Areas as Nonpoint Sources of Pollution." In M. R. Overcash and J. M. Davidson [eds.] *Environmental Impact of Nonpoint Source Pollution*. Ann Arbor Science Publications, Inc., Ann Arbor, Michigan, pp. 275-310. 1980.

2. Baker, J. L. "Hydrologic Effects of Conservation Tillage and Their Importance to Water Quality." In T. J. Logan, J. M. Davidson, J. L. Baker, and M. R. Overcash [eds.] *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Lewis Pub., Chelsea, Michigan, pp. 113-124. 1987.

3. Baker, J. L. and H. P. Johnson. "The Effect of Tillage System on Pesticides in Runoff from Small Watersheds." Trans. American Society of Agricultural Engineers, 22: 554-559. 1979.

4. Baker, J. L. and J. M. Laflen. "Runoff Losses of Surface-applied Herbicides as Affected by Wheel Tracks and Incorporation." *Journal of Environmental Quality*, 8: 602-607. 1979.

5. Baker, J. L. and J. M. Laflen. "Water Quality Consequences of Conservation Tillage." *Journal of Soil and Water Conservation*, 38(3): 186-193. 1983.

6. Baker, J. L. T. J. Logan, J. M. Davidson, and M. R. Overcash. "Summary and Conclusions." In T. J. Logan, J. M. Davidson, J. L. Baker, and M. R. Overcash [eds.] *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Lewis Pub., Chelsea, Michigan, pp. 277-281. 1987.

7. Bengtson, R. L., L. M. Southwick, G. H. Willis, and C. E. Carter. "The Influence of Subsurface Drainage Practices on Herbicide Loss." Paper 89-2130. American Society of Agricultural Engineers, St. Joseph, MI. 1989.

8. Bull, Len. "Residue and Tillage Systems in 1987 Corn Production." *Agricultural Resources: Inputs Situation and Outlook Report*, AR-13, ERS, USDA, February 1989.

9. Bull, Len. "Residue and Tillage Systems for Field Crops" Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Staff Report No. AGES 9310, July 1993.

10. Bull, Len and Herman Delvo. "Pesticide Use by Tillage System: 1988 and 1989 Corn and Soybeans" Unpublished report.

11. Dick, W. A. and T. C. Daniel. "Soil Chemical and Biological Properties as Affected by Conservation Tillage: Environmental Implications." In T. J. Logan, J. M. Davidson, J. L. Baker, and M. R. Overcash [eds.] *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Lewis Pub., Chelsea, Michigan, pp. 125-147. 1987.

12. Edwards, William M., M. J. Shipitalo, L. B. Owens, and W. A. Dick. "Factors Affecting Preferential Flow of Water and Atrazine Through Earthworm Burrows under Continuous No-till Corn." *Journal of Environmental Quality*. Vol. 22, No. 3 (1993).

13. Fawcett, Richard S. "Overview of Pest Management for Conservation Tillage Systems." In T. J. Logan, J. M. Davidson, J. L. Baker, and M. R. Overcash [eds.] *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Lewis Pub., Chelsea, Michigan, pp. 125-147. 1987.

14. Fawcett, Richard S., Dennis P. Tierney, Brian R. Christensen. "Impact of Conservation Tillage on Reducing Runoff of Pesticides into Surface Waters: A Review and Analysis." Accepted for publication in the *Journal of Soil and Water Conservation*. 1993.

15. Felsot, A. S., J. K. Mitchell, and A. L. Kenimer. "Assessment of Management Practices for Reducing Pesticide Runoff from Sloping Cropland in Illinois." *J. Environ. Qual.* 19: 539-545. 1990.

16. Fuller, Wayne, William Kennedy, Daniel Schnell, Gary Sullivan and Heon Jun Park. "PC CARP", Statistical Laboratory, Iowa State University, Ames, Iowa, 1986.

17. Glenn, S. and J. S. Angle. "Atrazine and Simazine in Runoff from Conventional and No-Till Corn Watersheds." *Agricultural Ecosystems and Environment*, 18: 273-280. 1987.

18. Glotfelty, D. E. "The Effects of Conservation Tillage Practices on Pesticide Volatilization and Degradation." In T. J. Logan, J. M. Davidson, J. L. Baker, and M. R. Overcash [eds.] *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Lewis Pub., Chelsea, Michigan, pp. 169-177. 1987.

19. Griffith, D.R., J.F. Moncrief, D.J. Eckert, J.B. Swan, and D.D. Breitbach. "Crop Response to Tillage Systems." In *Conservation Tillage Systems and Management, Crop Residue Management with No-till, Ridge-till, Mulch-till*. MidWest Plan Service, MWPS-45, First Edition, 1992, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, Iowa pp. 25-33.

20. Hall, J. K., N. L. Hartwig, and L. D. Hoffman. "Cyanazine Losses in Runoff from No-Tillage Corn in "Living" and Dead Mulches vs. Unmulched, Conventional Tillage." *Journal of Environmental Quality*, 13: 105-110. 1984.

21. Hall, J. K., R. O. Mumma, and D. S. W. Watts. "Leaching and Runoff Losses of Herbicides in a Tilled and Untilled Field." *Agricultural Ecosystems and Environment*, 37: 303-314. 1991.

22. Hanthorn, M. and M. Duffy. "Corn and Soybean Pest Management Practices for Alternative Tillage Strategies." Publication No. IOS-2, USDA/ERS, Washington, D. C., 1983.

23. Helling, C. S. "Effect of Conservation Tillage on Pesticide Dissipation." In T. J. Logan, J. M. Davidson, J. L. Baker, and M. R. Overcash [eds.] *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Lewis Pub., Chelsea, Michigan, pp. 179-187. 1987.

24. Kenimer, A. L., S. Mostaghimi, R. W. Young, T. A. Dillaha, and V. O. Shanholtz. "Effects of Residue Cover on Pesticide Losses from Conventional and No-tillage Systems." Trans. American Society of Agricultural Engineers, 30: 953-959. 1987.

25. Kinsella, Jim. "Notes on Weed Control with Herbicides in the Production of Row Crops." Presented to Conservation Technology Information Center Executive Meeting, March 30, 1993.

26. Martin, Alex R. and Gail A. Wicks. "Weed Control." In *Conservation Tillage Systems and Management, Crop Residue Management with No-till, Ridge-till, Mulch-till*. MidWest Plan Service, MWPS-45, First Edition, 1992, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, Iowa pp. 57-66.

27. MidWest Plan Service. "Conservation Tillage Systems and Management, Crop Residue Management with No-till, Ridge-till, Mulch-till", MWPS-45, First Edition, 1992, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, Iowa.

28. Onstad, C. A. and W. B. Voorhees. "Hydrologic Soil Parameters Affected by Tillage." In T. J. Logan, J. M. Davidson, J. L. Baker, and M. R. Overcash [eds.] *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Lewis Pub., Chelsea, Michigan, pp. 95-112. 1987.

29. Sander, K. W., W. W. Witt, and M. Barrett. "Movement of Triazine Herbicides in Conventional and Conservation Tillage Systems." In D. L. Weigmann [ed.] *Pesticides in Terrestial and Aquatic Environments*. Virginia Water Resources Center and Virginia Polytechnic Institute and State University, Blacksburg. pp. 378-382. 1989.

30. Sauer, T. J. and T. C. Daniel. "Effect of Tillage System on Runoff Losses of Surface-Applied Pesticides." *Soil Science Society of America Journal*, 51. 410-415. 1987.

31. U.S. Dept. of Agriculture, Economic Research Service, "Farmers Expand Use of Crop Residue Management." *Agricultural Resources: Cropland, Water, and Conservation Situation and Outlook Report*, AR-30, May 1993.

32. U.S. Dept. of Agriculture, Economic Research Service, "Tillage Systems." *Agricultural Resources: Inputs Situation and Outlook Report*, AR-29, February 1993.

33. U.S. Dept. of Agriculture, Economic Research Service, "Water Quality Effects of Crop Residue Management." *Agricultural Resources: Cropland, Water, and Conservation Situation and Outlook Report*, AR-30, May 1993.

34. U.S. Dept. of Agriculture, National Agricultural Statistics Service, "Agricultural Chemical Usage, 1992 Field Crops Summary." Ag Ch 1 (93), March 1993.

35. Wagenet, R. J. "Processes Influencing Pesticide Loss with Water under Conservation Tillage." In T. J. Logan, J. M. Davidson, J. L. Baker, and M. R. Overcash [eds.] *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Lewis Pub., Chelsea, Michigan, pp. 190-204. 1987.

36. Wauchope, R. D. "Effects of Conservation Tillage on Pesticide Loss with Water." In T. J. Logan, J. M. Davidson, J. L. Baker, and M. R. Overcash [eds.] *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Lewis Pub., Chelsea, Michigan, pp. 205-215. 1987.

37. Wauchope, R. D.,T. M. Buttler, A. G. Hornsby, P. W. M. AugustijnBeckers, and J. P. Burt. The SCS/ARS/CES Pesticide Properties Database for Environmental Decision-making. Published as Volume 123 (164 pages) of *Reviews of Environmental Contamination and Toxicology* by Springer-Verlag, New York. 1992.

38. Weber, J. B. and R. L. Warren. "Herbicide Behavior in Soils: A Pesticide/Soil Ranking System for Minimizing Ground Water Contamination." In Proceedings of the Northeastern Weed Science Society, 47, 1993.

Table B1--Corn acres treated with herbicide by tillage system for major producing States, 1990, 1991, and 1992 1/

Item	1990					1991					1992				
	Conventional 2/		Conservation			Conventional 2/		Conservation			Conventional 2/		Conservation		
	With plow	Without plow	Mulch till	No till	Ridge till	With plow	Without plow	Mulch till	No till	Ridge till	With plow	Without plow	Mulch till	No till	Ridge till
Planted acres (1,000)	10,072	34,253	9,556	4,026	893	8,778	33,518	12,027	5,074	953	7,543	30,862	15,383	7,652	1,410
Percent by tillage system	17	57	18	7	2	15	56	20	8	2	12	49	25	12	2
Percent residue remaining	2	16	38	67	48	2	16	37	67	46	2	16	37	64	45
Herbicide use:															
Percent of planted acres treated:	90	96	94	96	100	91	96	97	96	94	95	97	97	99	98
Percent of planted acres with:															
0 treatments	10	4	6	4	0	9	4	3	4	6	5	3	3	1	2
1 treatment	60	59	57	62	66	67	62	60	65	61	69	59	53	68	70
2 treatments	27	33	33	30	30	23	32	35	27	30	24	36	39	27	26
3 or more treatments	3	4	3	4	4	1	2	2	4	3	2	2	5	4	2
Acres treated (1,000)	9,047	32,934	8,962	3,846	893	7,949	32,150	11,674	4,895	894	7,191	29,828	14,878	7,541	1,379
1,000 pounds a.i. 3/	27,455	111,036	27,005	12,584	2,204	21,573	95,681	35,588	15,910	1,885	19,369	90,948	43,421	24,852	3,016
Pounds a.i. per treated acre 4/5/	3.03a	3.37ab	3.01b	3.27	2.47	2.73abc	2.98ad	3.05b	3.25cd	2.11	2.69abc	3.05a	2.92bd	3.30cd	2.19
Number of treatments 4/	1.38	1.43	1.42	1.40	1.39	1.27abcd	1.38a	1.40b	1.39c	1.38d	1.30ab	1.41ac	1.51bcde	1.35d	1.30e
1,000 acre-treatments 6/	12,484	46,962	12,753	5,400	1,238	10,123	44,366	16,323	6,802	1,235	9,329	42,004	22,408	10,206	1,789
Percent with:															
Single ingredient:	61	50	56	37	56	50	52	46	34	43	47	48	50	32	41
2-way combinations:	36	46	39	45	42	42	43	50	51	52	49	45	45	54	57
3-way and 4-way combinations:	3	4	5	18	2	8	5	4	15	5	4	7	5	14	2
Pounds a.i. per acre-treatment:															
Single ingredient:	1.62	2.01	1.75	1.29	1.45	1.55	1.69	1.75	1.10	1.12	1.50	1.60	1.62	1.25	0.90
2-way combinations:	3.03	2.64	2.51	2.47	2.13	2.63	2.56	2.50	2.76	1.72	2.57	2.62	2.19	2.78	2.20
3-way and 4-way combinations:	4.43	3.65	3.06	4.07	3.83	3.09	3.39	3.15	3.74	2.92	2.79	3.24	2.73	3.79	3.70
Average:	2.20	2.36	2.12	2.33	1.78	2.13	2.16	2.18	2.34	1.53	2.08	2.17	1.94	2.44	1.69
Insecticide use:															
Percent of planted acres treated:	35	32	37	31	48	29	30	35	27	63	28	28	32	25	60
Percent of planted acres with:															
0 treatments	65	68	63	69	52	71	70	65	73	37	72	72	68	75	40
1 treatment	33	30	33	30	35	28	28	31	23	24	28	26	30	23	38
2 treatments	2	2	4	1	13	1	2	3	3	27	0	2	1	2	17
3 or more treatments	0	0	0	0	0	0	0	1	1	12	0	0	1	0	5
Acres treated (1,000)	3,525	10,960	3,535	1,248	430	2,546	10,055	4,209	1,370	600	2,112	8,641	4,923	1,913	846
1,000 pounds a.i. 3/	4,089	12,275	3,913	1,186	576	2,546	10,658	4,377	1,192	666	2,281	8,036	4,923	1,588	761
Pounds a.i. per treated acre 4/	1.16	1.12	1.11	0.95	1.34	1.00	1.06	1.04	0.87	1.11	1.08	0.93	1.00	0.83	0.90
Number of treatments	1.04	1.10	1.12	1.05	1.27	1.05	1.10	1.13	1.17	1.88	1.01	1.06	1.11	1.08	1.48

1/ States include IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI. 2/ With and without the moldboard plow. 3/ Active ingredients. 4/ Numbers followed by the same letter are significantly different (t test) at the 5 percent level (16). 5/ Ridge tillage is significantly lower (pounds a.i. per acre) than all other systems in each year. 6/ Acre-treatments = acres treated times number of treatments.

Table B2--Corn acres cultivated for weed control by tillage system for major producing States, 1990, 1991, and 1992 1/

Item	1990					1991					1992				
	Conventional 2/		Conservation			Conventional 2/		Conservation			Conventional 2/		Conservation		
	With plow	Without plow	Mulch till	No till	Ridge till	With plow	Without plow	Mulch till	No till	Ridge till	With plow	Without plow	Mulch till	No till	Ridge till
Weed control cultivations:															
Percent of planted acres cultivated	74	73	69	29	97	69	71	70	31	100	76	77	78	32	100
Percent of planted acres with:															
0 cultivations	26	27	31	71	3	31	29	30	69	0	24	23	22	68	0
1 cultivation	49	52	47	16	22	50	54	57	21	31	53	61	56	26	22
2 cultivations	21	18	20	13	72	16	15	13	10	67	19	15	20	5	77
3 or more cultivations	4	3	2	1	3	3	1	1	0	2	4	1	2	1	1
Cultivated acres:															
Average no. of cultivations	1.4	1.3	1.3	1.5	1.8	1.3	1.3	1.2	1.3	1.7	1.4	1.2	1.3	1.2	1.8

1/ States include IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI. 2/ With and without the moldboard plow.

Table B3--Northern soybean acres treated with herbicide by tillage system for major producing States, 1990, 1991, and 1992 1/

Item	1990					1991					1992				
	Conventional 2/		Conservation			Conventional 2/		Conservation			Conventional 2/		Conservation		
	With plow	Without plow	Mulch till	No till	Ridge till	With plow	Without plow	Mulch till	No till	Ridge till	With plow	Without plow	Mulch till	No till	Ridge till
Planted acres (1,000)	8,306	18,516	7,588	1,637	353	6,896	18,549	9,583	3,470	351	4,681	16,816	11,130	5,292	231
Percent by tillage system	23	51	21	4	1	18	48	25	9	1	12	44	29	14	1
Percent residue remaining	2	16	39	73	51	2	17	38	73	50	2	17	39	70	53
Herbicide use:															
Percent of planted acres treated:	97	97	95	94	100	95	97	98	94	100	99	99	99	98	100
Percent of planted acres with:															
0 treatments	3	3	5	6	0	5	3	2	6	0	1	1	1	2	0
1 treatment	52	61	52	39	50	61	61	52	46	46	59	59	54	44	83
2 treatments	40	31	38	46	50	33	32	41	40	37	37	37	41	44	8
3 or more treatments	5	5	5	9	0	1	4	5	9	17	3	3	4	10	9
Acres treated (1,000)	8,034	17,988	7,192	1,543	353	6,583	17,966	9,397	3,275	351	4,619	16,555	10,967	5,161	231
1,000 pounds a.i. 3/	12,643	23,807	9,692	3,415	404	8,583	22,136	12,002	4,975	639	5,234	18,855	11,986	6,869	165
Lbs. a.i. per treated acre 4/	1.57abcd	1.32ae	1.35bf	2.21cefg	1.14dg	1.30	1.23a	1.28	1.52ab	1.00b	1.13a	1.14b	1.09c	1.33abcd	0.72d
Number of treatments 4/	1.52	1.42a	1.52	1.70a	1.50	1.38abc	1.42def	1.53ad	1.61be	1.82cf	1.42ab	1.43cd	1.50ac	1.67bde	1.27e
1,000 acre-treatments 5/	12,246	25,523	10,943	2,630	529	9,065	25,485	14,422	5,274	639	6,581	23,719	16,466	8,601	293
Percent with:															
Single ingredient:	63	59	67	41	51	65	57	64	53	75	65	55	62	56	64
2-way combinations:	27	29	23	40	43	25	32	28	30	16	26	34	29	26	26
3-way and 4-way combinations:	10	12	10	19	6	10	11	8	17	9	9	11	9	18	10
Pounds a.i. per acre-treatment:															
Single ingredient:	0.78	0.67	0.69	0.42	0.53	0.61	0.64	0.65	0.42	0.24	0.56	0.59	0.56	0.46	0.18
2-way combinations:	1.32	1.20	1.09	1.61	0.84	1.51	1.04	1.04	1.25	1.68	1.06	0.94	0.97	0.88	0.84
3-way and 4-way combinations:	1.81	1.61	1.76	2.54	2.19	1.77	1.57	1.58	2.00	1.12	1.72	1.42	1.11	1.72	2.32
Average:	1.03	0.93	0.89	1.30	0.76	0.95	0.87	0.83	0.94	0.55	0.80	0.79	0.73	0.80	0.56

1/ States include IL, IN, IA, MN, MO, NE, and OH. 2/ With and without the moldboard plow. 3/ Active ingredients. 4/ Numbers followed by the same letter are significantly different (t test) at the 5 percent level (16). 5/ Acre-treatments = acres treated times number of treatments.

Table B4--Northern soybean acres cultivated for weed control by tillage system for major producing States, 1990, 1991, and 1992 1/

Item	1990					1991					1992				
	Conventional 2/		Conservation			Conventional 2/		Conservation			Conventional 2/		Conservation		
	With plow	Without plow	Mulch till	No till	Ridge till	With plow	Without plow	Mulch till	No till	Ridge till	With plow	Without plow	Mulch till	No till	Ridge till
Planted acres (1,000)	8,306	18,516	7,588	1,637	353	6,896	18,549	9,583	3,470	351	4,681	16,816	11,130	5,292	231
Percent planted with row planter	80	75	79	44	100	80	74	73	42	100	80	66	74	23	100
Weed control cultivations:															
Percent of row planted acres that were cultivated	89	86	85	26	100	87	83	87	15	84	86	79	81	22	96
Percent of row planted acres with:															
0 cultivations	11	14	15	74	0	13	17	13	85	16	14	21	19	78	4
1 cultivation	39	50	51	13	25	46	54	58	6	29	50	56	57	18	55
2 cultivations	44	33	31	13	66	37	27	27	9	38	32	21	23	4	41
3 or more cultivations	6	3	3	0	9	4	2	2	0	17	4	2	1	0	0
Cultivated acres:															
Average number of cultivations	1.6	1.6	1.4	1.5	1.8	1.5	1.4	1.4	1.6	2.5	1.5	1.3	1.3	1.5	1.4

1/ States include IL, IN, IA, MN, MO, NE, and OH. 2/ With and without the moldboard plow.

Table B5--Southern soybean acres treated with herbicide by tillage system for major producing States, 1990, 1991, and 1992 1/

Item	1990				1991				1992			
	Conventional 2/		Conservation 3/		Conventional 2/		Conservation 3/		Conventional 2/		Conservation 3/	
	With plow	Without plow	Mulch till	No till	With plow	Without plow	Mulch till	No till	With plow	Without plow	Mulch till	No till
Planted acres (1,000)	417	9,148	845	1,440	302	8,703	617	1,178	297	8,321	420	1,442
Percent of total planted acres	4	77	7	12	3	81	6	11	3	79	4	14
Percent previous crop residue	1	8	43	74	1	7	42	72	1	6	43	65
Herbicide use												
Percent of planted acres treated:	89	93	90	96	86	92	92	95	78	95	97	98
Percent of planted acres with:												
0 treatments	11	7	10	4	14	8	8	5	22	5	3	2
1 treatment	54	48	50	50	52	50	65	39	63	45	53	40
2 treatments	28	35	33	36	30	35	27	38	15	35	39	43
3 or more treatments	7	10	7	10	4	7	0	18	0	15	5	15
Acres treated (1,000)	370	8,505	758	1,379	260	8,041	565	1,126	233	7,882	407	1,414
1,000 pounds a.i. 4/	449	10,104	792	2,678	315	9,019	506	2,238	320	9,175	467	1,985
Pounds a.i. per treated acre 5/	1.21a	1.19b	1.05c	1.94abc	1.21a	1.12bc	0.89bd	1.99acd	1.37	1.16a	1.15b	1.40ab
Number of treatments 5/	1.47	1.61	1.52	1.58	1.44a	1.55bc	1.29bd	1.82acd	1.19abc	1.72ad	1.50bde	1.78ce
1,000 acre-treatments 6/	543	13,691	1,151	2,182	376	12,504	732	2,048	277	13,589	611	2,527
Percent with:												
Single ingredient:	53	67	67	53	53	60	43	46	61	62	62	53
2-way combinations:	45	27	24	32	44	33	40	36	39	31	31	31
3-way and 4-way combinations:	2	6	9	15	3	7	17	18	0	7	7	16
Pounds a.i. per acre-treatment:												
Single ingredient:	0.64	0.58	0.50	0.54	0.65	0.61	0.56	0.51	0.89	0.54	0.65	0.49
2-way combinations:	0.97	0.92	0.88	1.84	0.91	0.80	0.70	1.20	1.56	0.83	0.90	0.95
3-way and 4-way combinations:	2.75	1.65	1.56	2.35	2.76	1.29	1.02	2.36	0.00	1.21	1.11	1.46
Average:	0.83	0.74	0.69	1.23	0.84	0.72	0.69	1.09	1.15	0.68	0.76	0.79

1/ States include AR, GA, KY, LA, MS, NC, and TN. 2/ With and without the moldboard plow. 3/ No ridge tillage reported. 4/ Active ingredients.
5/ Numbers followed by the same letter are significantly different (t test) at the 5 percent level (16). 6/ Acre-treatments = acres treated times number of treatments.

Table B6--Southern soybean acres treated with fertilizer and cultivated for weed control by tillage system for major producing States, 1990, 1991, and 1992 1/

Item	1990				1991				1992			
	Conventional 2/		Conservation 3/		Conventional 2/		Conservation 3/		Conventional 2/		Conservation 3/	
	With plow	Without plow	Mulch till	No till	With plow	Without plow	Mulch till	No till	With plow	Without plow	Mulch till	No till
Planted acres (1,000)	417	9,148	845	1,440	302	8,703	617	1,178	297	8,321	420	1,442
Percent planted with row planter	86	76	62	61	82	76	76	88	76	75	73	63
Weed control cultivations:												
Percent of row planted acres that were cultivated	79	75	60	11	71	74	43	16	78	75	45	10
Percent of row planted acres with:												
0 cultivations	21	25	40	89	29	26	57	84	22	25	55	90
1 cultivation	20	17	13	3	20	15	10	8	19	13	9	2
2 cultivations	35	32	29	3	30	31	15	6	28	36	29	6
3 or more cultivations	24	26	10	5	21	28	10	2	31	26	7	2
Cultivated acres:												
Average number of cultivations	2.1	2.2	2.2	2.2	2.0	2.3	1.8	1.7	2.2	2.3	1.9	1.9

1/ States include AR, GA, KY, LA, MS, NC, and TN. 2/ With and without the moldboard plow. 3/ No ridge tillage reported.

Factors Influencing Agrichemical Use in Non-Irrigated Corn Production

Biing-Hwan Lin, Harold Taylor, Herman Delvo, and Len Bull [1]

Abstract: Fertilizer and pesticide use has contributed to agricultural productivity growth and raised concerns about health and environmental risks. Identification of less chemical-intensive production practices is an important step towards reducing agrichemical use. Field-level data for non-irrigated corn produced in 10 States for the period of 1990-1992 are analyzed. The major findings are: (1) nitrogen and herbicide use can be greatly reduced by switching from broadcast to band applications and from pre-plant to after-plant applications; (2) crop rotations are the most effective means for reducing insecticide use, but crop rotations have only limited effect on the use of nitrogen and herbicides; and (3) a switch from conventional tillage to conservation tillage does not necessarily increase nitrogen and pesticide use.

Keywords: Fertilizer use, pesticide use, tillage systems, crop rotations, commodity program, timing and method of application.

Introduction

Fertilizer and pesticide use has contributed to the modernization of agriculture, which is characterized by major changes in production techniques, shifts in input use patterns, and an impressive record of productivity growth. Agrichemical use, however, is also viewed as a double-edged sword because of concern about chemical residues in food and water, and other potential health and environmental risks.

An array of fertilizer and pest management methods are practiced by farmers, resulting in a diverse pattern of agrichemical use. Additionally, agrichemical use is known to be influenced by other factors, including government programs and weather. By simultaneously analyzing the effects of production practices and other factors (government programs, weather) on chemical use, less chemical-intensive practices in non-irrigated corn production are identified. The empirical results can be used to measure the potential reduction in chemical use in corn production by adopting less chemical-intensive practices.

Literature

Extensive research has been conducted to analyze the effects of some production practices and government programs on agrichemical use. In this study, the results reported in the literature are compared with the empirical results of an analysis of field-level data collected through the USDA Cropping Practices Survey (CPS) on corn. The literature review is focused on the production practices included in the survey.

Tillage Practices

Over the past three decades, farmers have adopted several distinct tillage practices to prepare fields for planting. Over time, tillage systems have been defined in a number of ways and have different meanings to the agricultural community, making it difficult to develop historical trends in tillage practices (10, 13). The delineation of tillage practices can be thought of as a continuum based on the amount of plant residue left on the field and the extent of soil disturbance. No-till and conventional-till (especially with the use of the moldboard plow) comprise the extremes of the continuum.

Conventional-till involves extensive field preparation prior to planting, incorporating 70 percent or more of the plant residue into the soil. The use of the moldboard plow in conventional-till almost eliminates plant residue, making it useful to classify conventional-till into two practices--conventional-till with and without the moldboard plow.

Conservation tillage includes those systems (no-till, ridge-till, and mulch-till) that leave 30 or more percent of the plant residue on the soil surface after planting. No-till is a practice by which plant residue is left virtually undisturbed on the field surface. Planting is completed in a narrow seedbed or slot created by the planter or drill. Ridge-till is a system where the soil is left undisturbed from harvest to planting. At planting the ridges are cleared of plant residue for seedbed preparation, but plant residue is left undisturbed in the row middles. Mulch-till encompasses all other systems where the soil is disturbed prior to planting but meets the criteria of more than 30 percent residue cover after planting. Detailed definitions of various tillage systems can be found in Bull (2).

Adoption of conservation-till in major field crops, such as corn and soybeans, increased in the early 1980's as farmers attempted to save labor, fuel, and machinery costs and

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to achieve higher profits. Still, conventional-till has remained the predominant tillage practice in corn and soybean production. Reasons cited for farmers' reluctance to adopt conservation tillage practices prior to 1980 were fear of reduced yields, greater weed problems, additional capital investment in machinery, and reluctance to change practices (13).

Since 1985, conservation tillage practices have increased steadily. Between 1987 and 1992, on corn acres, conventional-till with the moldboard plow declined from 21 to 12 percent, conventional-till without the moldboard plow dropped from 60 to 49 percent, mulch-till increased from 14 to 25 percent and no-/ridge-till rose from 5 to 14 percent (40, 42). Between 1988 and 1992, on soybean acres, conventional-till with the moldboard plow decreased from 22 to 10 percent, conventional-till without the moldboard plow declined from 63 to 53 percent, while mulch-till increased from 12 to 22 percent and no-/ridge-till rose from 4 to 15 percent (42).

Increases in the adoption of conservation tillage are mainly caused by the conservation compliance provisions of the 1985 and 1990 farm acts that require farmers to implement conservation plans on highly erodible land (HEL) by 1995 or lose program benefits. There currently are 148 million acres of cropland that have been determined to be HEL, of which 141 million acres have approved USDA conservation plans. These plans include crop residue management as part of the recommended treatment on about 75 percent of the 110 million HEL acres planted to crops.

The effects of conservation tillage on input use, crop yields, and economic returns have not been conclusively determined (13). A common view is that conservation tillage requires more nitrogen fertilizer than conventional tillage because cooler and more moist soils slow the mineralization of nitrogen and promote denitrification (8). Fewer tillage operations and mechanical cultivations for weed control with conservation tillage may require additional herbicide use. More herbicides, insecticides, and fungicides may be required with conservation tillage because the additional plant residue provides an environment for pest development and ties up a portion of the pesticide material applied.[2]

The above views have not been supported in some empirical studies. In an analysis of field-level data for corn and soybean production in 1980, Duffy and Hanthorn (13) reported almost no difference in chemical use between conventional and conservation tillage systems. Consequently, Logan *et al* (26) conclude that the perceived greater use of nitrogen and pesticides with conservation tillage appear to be unfounded. Obviously, agrichemical use is influenced by an array of factors, and some of them (such as cropping patterns, application timing and methods, government program, etc.) may have greater impacts than tillage systems.

Rotation

Crop rotation involves planting different crops successively in the same field. Compared to continuous cropping, crop rotation provides two types of benefits related to chemical use. Crop rotations maintain soil moisture and fertility, and thus reduce farm-level demand for fertilizer. It has been shown that rotations can increase grain crop yields beyond those achieved with continuous cropping under similar conditions (35, 5, 17, 19, 33, 43).

Another major benefit of crop rotations is the control of insects, diseases, and weeds; particularly insects and diseases that attack the plant roots (6). Rotating crops to control insects has a long history and was one of the most important methods of insect control before insecticides came into general use (37). During the early 1940's, little or no insecticides were applied to corn, and losses to insects were small. Since then insecticide use in corn production has increased dramatically and losses to insects also increased appreciably, mainly due to increased continuous cropping (34).

Rotating corn with another crop, such as soybeans, can significantly reduce the amount of insecticides needed for treating corn rootworm larvae, a major corn insect. Among the 60.4 million corn acres in the 17 major producing States in 1991, 24 percent were in 3-year corn, 12 percent were in 2-year corn, 46 percent were in the corn and soybean sequence, and the remaining 18 percent had other crops (mainly fallow, alfalfa, wheat, and oats) as the previous crop (41).

Crop rotations can be effective in interrupting the development of the disease and weed life cycle (27, 39). Rotating crops is possibly the oldest and most widely practiced diversification strategy used in agricultural production for disease control (7). Plant pathogens usually have narrow host ranges and will not survive in the absence of the host. For example, crop rotations are known to reduce many diseases in wheat and tobacco production (36).

Weeds having the same life cycle as the crop tend to increase rapidly when the crop is grown continuously. For example, in continuous corn, summer annual weeds, both grasses and broadleaves, would tend to dominate. When corn is followed by winter wheat, the intensities of the summer annual weeds decrease because winter wheat competes with weeds in the early spring, thus reducing germination and their further establishment (39). While some weed control can be accomplished by crop rotations, weed control usually is not a primary purpose of crop rotations (45).

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[2] Most studies analyzing differences in input use among tillage systems have been experimental in nature and for particular soil types (13). Because agricultural production is subject to many sources of variability, experimental results may not prevail uniformly across highly varied conditions (25). Therefore, care should be exercised in generalizing the results of plot studies for policy-making purposes.

Application Timing and Methods

Timing and method of application greatly influence the amount of agrichemicals applied and thus have important agronomic, economic, and environmental ramifications. Many experimental plot studies have been conducted by plant and weed scientists to examine the effects of timing and method of chemical applications on nutrient uptake by plants, weed control, and yields. However, little analysis has been done with farm-level data.

Pre-plant applications of nitrogen are relatively inefficient because of denitrification, leaching, and run-off, whereas late-applied (sidedressed) nitrogen is used more effectively by plants (15). In an experimental plot study, it was shown that the corn yield achievable with 160 pounds of fall-applied nitrogen could also be obtained with only 80 pounds of sidedressed nitrogen (23). However, price incentives, resource limitations, and the potential for a wet spring often encourage farmers to apply some nitrogen in the fall. Consequently, split nitrogen applications provide farmers with more flexibility than a single application either before planting or in later spring (30). In 1992, about 28 million acres of corn in the 17 major producing States (or 39 percent of planted acres) received a single, pre-plant nitrogen application; 32 million acres (or 49 percent of planted acres) received split nitrogen applications before, at, or after seeding; 3 percent of acres were not treated with nitrogen; and the remaining 9 percent were treated exclusively either at or after seeding.

Soil-applied, pre-emergence herbicides have been the foundation of row crop weed control for the past 30 years (22). In 1992, about 41 and 64 percent of corn and soybean planted acres, respectively, received pre-plant herbicides. (Herbicides applied before planting are usually, but not necessarily, pre-emergence herbicides). Post-emergence herbicides are considered more environmentally sound than pre-emergence herbicides because they have little or no soil residual activity. There is a trend toward using more post-emergence herbicides, which is expected to accelerate in the future for two reasons (22). First, the introduction of new post-emergence herbicides and the sharp decrease in cost of several older post-emergence herbicides. Second, conservation tillage has increased and will continue to increase, limiting the option of incorporating pre-emergence herbicides into the soil.

Farmers are expected to pay more attention to the use of integrated pest management (IPM) in weed control. With IPM, farmers determine the need for treatment and select the herbicide after the weed problem has been identified. The weed IPM strategy has been augmented in recent years by research data on weed threshold levels, and the development of computer software programs to aid farmers in evaluating various weed control strategies. However, there are limitations to total post-emergence programs. Greater attention must be paid to management details, such as close monitoring of weather conditions and weed development. Post-emergence herbicides provide good control of annual weeds when they are small, but may not be effective in controlling large weeds. Because rain may prevent timely applications of pest-emergence herbicides, total post-emergence programs are considered more risky than pre-emergence programs.

Fertilizers and pesticides are generally applied as banded or broadcast treatments. The best method of fertilizer application depends on many factors, including soil fertility and tillage system (11). In general, broadcast application requires a rate much greater than the banded rate. But farmers may choose to broadcast fertilizer in order to build up soil fertility or because of economic reasons; broadcast saves labor and time at planting and allows application of bulk materials that may be lower priced.

Herbicide application rates per acre vary greatly between application methods. In general, the per-acre herbicide application rate for banding is about one-third of the broadcast rate for corn and soybeans. While band application saves materials and thus is more environmentally friendly, the broadcast method saves labor and time because the weeds in the row middles are also controlled, reducing the need for mechanical cultivation.

Farm Programs

The literature is replete with analyses of the effects of farm programs on chemical use. The majority of research findings suggest that farm programs, especially commodity programs, have increased chemical use in agricultural production (38, 20, 31, 44, 17, 4). However, the findings were not supported in some studies (16, 18). As stated by Mjelde *et al* (29) "Input intensity differences between program participants and non-participants is a complicated issue." Indeed, farm programs may influence agrichemical use through several channels (28, 44, 31), as discussed below.

First, farm programs raise prices of and reduce price variations in program crops. Higher prices mean higher marginal revenues for inputs, and hence motivate additional input use. For risk-averse farmers the price guarantee provided by target prices or loan rates may encourage additional non-land input use.

Second, deficiency payments are tied to the base acreage and program yields. Base acreage (before 1990) and program yields (before 1985) were computed by means of a 5-year moving average. The need to maintain base acreage for program crops imposed inflexibility in cropping patterns (9). The cross-compliance provision of the Food Security Act of 1985 served as an effective financial barrier to diversification into other program crops, for which farmers do not have base acres. The inflexible cropping patterns induced by farm programs are dominated by major program crops (21, 14) because of the need to maintain base acreage. Because some program crops (mainly corn) are more agrichemical-intensive than non-program crops (with the exception of fruits and vegetables), the base acreage requirement has contributed to increased chemical use.

The 1990 farm act permits farmers the flexibility to plant 15 to 25 percent of their base acreage to program or specified other crops without losing future base acreage, hence providing some flexibility in cropping patterns. Before

1985, documentation of higher yields contributed directly to increased program payments in future years. Therefore, farmers might have applied additional non-land inputs to increase future program benefits. Currently, program yields have been frozen at the 1981-1985 level so the incentive for increasing yields to gain future program benefits has been removed.

Third, farm programs may affect agrichemical use through the Acreage Reduction Program (ARP). When ARP is announced, farmers have to set aside a certain percentage of the base acreage in order to be eligible for loans and deficiency payments. ARP may increase or decrease agrichemical use.

Because few chemicals are applied to set-aside acres, a reduction in total cropped area may reduce total agrichemical use. Further, cover crops can be planted on set-aside land as green manure and hence reduce fertilizer needs the following year. Also, surplus fixed factors (e.g., equipment and management) can substitute for agrichemical inputs in the short run (3). For example, mechanical cultivation can substitute for herbicides, and scouting to determine economic thresholds may improve the efficiency of insecticide use.

However, if the quality of land in a farm is heterogenous, then farmers may actually idle poor quality land. This slippage may affect per-acre agrichemical use in two ways: agrichemical use (e.g., fertilizers) increases with land quality; and ARP reduces total supply of the program crop, and bids up the price and marginal return of the program crop.

Empirical Results

The influence of production practices and government programs on agrichemical use is a complex issue, and contradicting views and research findings exist in the literature. Further, results of experimental plot studies may not prevail in actual farm operations. In order to more accurately identify and quantify the factors that influence agrichemical use, we conducted a regression analysis utilizing cross-sectional, field-level production data.

Data

Detailed data on some input use (mainly fertilizer and pesticides), selected production practices, commodity program participation, and yields have been collected annually since 1990 through the USDA's Cropping Practices Surveys for major field crops. The data collected on corn for 1990 through 1992 are analyzed.

The corn survey covers 17 major producing States. Because irrigated and non-irrigated corn production tend to have different agrichemical use patterns and because the majority of corn acres are non-irrigated, the analysis was focused on non-irrigated corn production. Similarly, the analysis was focused on corn grain production (sweet corn, silage, and other corn acres are excluded). Since irrigated corn production is concentrated in Nebraska and Kansas, all observations in these two States were excluded. To further reduce variations in agrichemical use due to regional factors (such as climate, distinct pest problems, etc.), observations from Georgia, North Carolina, Pennsylvania, South Carolina, and Texas were also excluded. The remaining 10 States (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, South Dakota, Wisconsin, and Kentucky) were included in the analysis.

Common tillage practices reported include conventional-till with or without the moldboard plow, mulch-till, and no-till. Ridge-till was reported for less than 1 percent of the remaining observations and thus were excluded from the analysis, resulting in a total of 9,287 observations that were available for analysis, representing 66 percent of U.S. corn production.

Nitrogen, herbicides, and insecticides are the major agrichemicals used in corn production, and analyzed in this study. Nitrogen use was measured in terms of pounds per acre, while two measures of herbicide and insecticide inputs were used: total pounds or total cost per acre of active ingredients applied. Many pesticide active ingredients are used in corn production and their prices and efficacy vary widely. Prices of herbicide and insecticide active ingredients were obtained from various sources. NASS's annual Pesticide Price Survey provided State-level prices for selected herbicides and insecticides. The NASS price information was supplemented with national average prices reported by DPRA Inc. (12) or manufacturers suggested retail price lists.

Weather affects nitrogen and pesticide use. Rain before winter freeze-up causes nitrogen run-off and leaching while excessive rain in the spring may result in wet fields and may thus prevent nitrogen application. The level of pest infestation strongly influences pesticide use.

Temperature was used as a proxy for pest infestation. County-level precipitation and temperature on a monthly basis were obtained from the National Oceanic and Atmospheric Administration. [3]

Estimation Procedures and Limitations

While a random sample was drawn for each of the 10 States analyzed, samples across States had unequal chances of selection. Each observation was weighted by the number of acres it represented in the regression estimation. Most of production practices were recorded as whether or not they were adopted, and thus were represented by dummy variables. When there were multiple dummy variables created for a particular production practice, one of the dummy variables was excluded from the estimation and the excluded variable was termed the base variable.

For example, there were four tillage systems analyzed and conventional-till with the moldboard plow was the base

[3] The number of growing degree days has been suggested as a good proxy for pest infestation (1). Some States, such as Nebraska, have regularly reported growing degree days for various locations. However, a compilation for the 10 States during 1990-1992 was impractical.

variable. The t-values of the estimated coefficients for the three tillage systems (conventional-till without the moldboard plow, mulch-till, and no-till) indicated whether these tillage systems used significantly different amounts of chemicals (or require different treatment costs) than the base tillage variable. A separate t-test was performed in order to find out if a particular pair of the three included tillage systems (or other production practices) used different amounts of chemicals.

When preliminary analyses indicated that both participation in the feedgrain program and cropping sequences influenced chemical use, interactive dummy variables were used in the final analysis. These interactive variables showed whether program effects varied across cropping sequences, and vice versa.

Theoretically, numerous interactive dummy variables could be created among the factors included in the analysis, but we focused on the interactive effects between commodity program and cropping sequences because the literature suggests that the commodity program has imposed inflexibility in cropping sequences. Given the degree of inflexibility in cropping sequences (i.e., the probability of switching from a diversified cropping pattern to continuous corn under program), the regression results could be used to calculate the direct effect of commodity program on chemical use as well as the "indirect" effect channelled through changes in cropping sequences. The influence of commodity programs on cropping sequences was not investigated in this study. Therefore, the program effect was only partially analyzed since only the direct effect is estimated.

Some empirical results reported in this study need to be interpreted with care. Agrichemical use varies greatly by region (e.g., pest infestation is related to climate). In the analyses, we included county-level precipitation and temperature and the corn maturity length, which also varied by region. Thus, the estimated coefficients of these variables might have captured the effects of some regional factors that were not represented in the model. However, the inclusion and exclusion of these variables, in general, had little impact on the estimated coefficients of the production practices which were the focus of the study.

Nitrogen Use

Farmers often determine their nitrogen application rates based on their target yields. The CPS is an add-on to the USDA Objective Yield Survey, and about 40 percent of the CPS samples overlapped with the OYS samples and thus reported yields. Those CPS samples that had no yield information were excluded from the analysis of nitrogen use, resulting in 3,597 observations being analyzed. Table C-1 lists parameter estimates, t-values, and other summary statistics of the estimated linear regression model for nitrogen use. The R^2 and adjusted R^2 were around 29 percent, indicating a reasonable goodness-of-fit for cross-sectional data.

Three tillage systems were represented by dummy variables, and conventional-till with the moldboard plow was the base variable. The t-values reported in table C-2 suggest that farmers who practiced conservation tillage (mulch-till and no-till) used about the same amount of nitrogen as farmers who practiced conventional-till with the moldboard plow, at the 5 percent significance level. Separate t

Table C-1. Factors affecting nitrogen use

	Coeff.	t-value
	lbs/ac	
Constant	-0.97	-0.12
Convent-till with MBP 1/	base variable	
Convent-till w/o MBP 2/	6.02	2.40
Mulch-till	3.72	1.27
No-till	1.99	0.56
3-year Corn	base variable	
2-year Corn	-3.33	-1.12
Corn/Soybean	-3.76	-1.65
Corn/Other	-9.22	-3.16
Pre-plant Applications	4.29	2.52
Band Applications	-56.99	-16.17
Program Participation	-0.63	-0.33
Early Season Maturity	-11.80	-6.03
Medium Season Maturity	base variable	
Full Season Maturity	3.53	1.45
Precipitation Winter 3/	3.75	11.77
Precipitation Spring 3/	-0.72	-2.38
Manure Applied	-12.96	-5.70
Nitrogen Inhibitor	17.56	6.49
Yield 4/	0.23	7.91
Seeding Rate 5/	3.50	11.55
Year 1990	7.33	2.33
Year 1991	9.90	3.35

R-Square = 0.294, Adj. R-Square = 0.291

1/ Conventional-till the moldboard plow.
2/ Conventional-till without the moldboard plow.
3/ Measured in inches.
4/ Measured in bushels per acre.
5/ Measured in 1,000 kernels per acre.

Table C-2. Factors affecting herbicide use and cost

	Use		Cost	
	Coeff.	t-value	Coeff.	t-value
	lbs/ac		$/ac	
Constant	-2.70	-5.60	4.66	1.80
Convent-till with MBP	base variable			
Convent-till w/o MBP	0.15	3.05	1.16	4.57
Mulch-till	0.11	1.99	1.89	6.60
No-till	0.18	2.66	2.54	7.03
3-Year Corn & Program	base variable			
2-year Corn & Program	-0.03	-0.39	-0.11	-0.31
Soybean/Corn & Program	-0.04	-0.88	-0.60	-2.33
Other/Corn & Program	-0.19	-2.92	-1.22	-3.46
3-Year Corn & No Program	-0.10	-1.30	-1.63	-3.83
2-year Corn & No Program	-0.38	-4.20	-2.74	-5.65
Soybean/Corn & No Program	-0.17	-2.76	-1.33	-4.12
Other/Corn & No Program	-0.15	-1.70	-1.98	-4.24
Mechanical Cultivation	-0.17	-7.01	-0.65	-5.10
Pre-Plant Applications	0.28	7.81	-1.76	-9.32
Band Applications	-0.61	-11.53	-3.14	-11.13
Farmer Self Applications	-0.05	-1.59	-1.20	-7.28
Cover Crop	-0.86	-1.06	-1.07	-2.46
Seeding Rate	0.06	12.30	0.54	19.43
Temperature 1/	0.07	9.75	0.04	1.22
Year 1990	0.20	5.24	-2.05	-10.11
Year 1991	-0.38	7.14	-1.08	-3.84
R-Square	0.10		0.12	
Adj. R-Square	0.09		0.11	

1/ Measured in degrees Fahrenheit.

tests, unreported, further indicated no differences in nitrogen use between mulch-till, no-till, and conventional-till without the moldboard plow. These findings are consistent with the results reported by Duffy and Hanthorn (13), and do not support the common view that reduced tillage tends to require more nitrogen.

Four cropping sequences were analyzed, including 3-year corn, 2-year corn, corn-soybeans (denoted by corn/soybean hereafter), and corn-other crops (neither corn nor soybean was planted before corn, denoted by corn/other). The base variable is 3-year corn. Farmers who planted 3-year corn used more nitrogen, at the 10 percent significance level, than farmers who planted corn following a crop other than corn. However, farmers who grew corn for only two consecutive years did not use significantly more nitrogen than farmers who planted corn following soybeans.

Even though soybeans are known to provide rotational benefit in terms of nutrient requirement, many farmers did not appear to give credit to the residual nitrogen. Farmers who followed the corn/other sequence applied less nitrogen than farmers who planted corn for 2 or 3 consecutive years. Alfalfa and fallow accounted for around 50 percent of other crops in corn/other acres.

Application timing and methods greatly influence nitrogen use. Farmers were categorized by whether or not they applied nitrogen only before planting. Because of greater potential for denitrification, run-off, and leaching associated with pre-plant nitrogen applications, farmers who completed nitrogen applications before planting were expected to use more nitrogen than farmers who did not rely solely on pre-plant applications. Broadcast and band are the two predominant nitrogen application methods.[4] Broadcast application rates are much higher than banded rates. The empirical results indicate that indeed higher application rates were associated with pre-plant applications as compared to other application timings, and especially with the broadcast method which used 57 pounds more nitrogen per acre than the band method.

The empirical results suggest that participation in the feedgrain program did not directly encourage more nitrogen use during 1990-1992. However, because a small percent of soybean acres were treated with nitrogen and low rates were applied to treated acres, the corn/soybean sequence received much less nitrogen than continuous corn over a 2-year period. Consequently, we need to study the rotation decision-making in order to improve our understanding of the total program effect on nitrogen and pesticide use.

Actual yields were treated as the proxy for target yields (the previous yield of the field was unknown), and the yield variable was significantly and positively related to nitrogen application rates. Seeding rates reflect the density of the crop, and had positive effect on nitrogen application rates. Three maturity lengths of corn were planted in the 10 States, including early season (109 days or less), medium (110-119 days), and full season (120 days or more). Nitrogen application rates increased with the length of maturity, but the difference between medium and full season maturity varieties was not statistically significant.

Manure is a substitute for nitrogen. A dummy variable was created to signify manure application to the corn field (the actual amount of manure applied was unknown). The results indicate that the manure-treated fields received an average of 13 pounds less nitrogen than other fields.

The use of nitrogen inhibitors, which slows down leaching of nitrogen and hence improves nitrogen efficiency, was found to be positively correlated with nitrogen application rates. An earlier study suggests that the use of nitrogen inhibitors improved corn yields in 1990 (24). If this is the case, farmers can use nitrogen inhibitors and reduce nitrogen use without adversely impacting yields. The use of nitrogen inhibitors is a relatively new technology which has been adopted by a fairly small percentage of corn farmers. It is likely that farmers may be reluctant to change nitrogen use when they are experimenting with nitrogen inhibitors.

Precipitation during January through March resulted in increased nitrogen application rates. The result is reasonable because rainfall during this period increases the amount of nitrate run-off and leaching, and thus requires additional nitrogen input. With good moisture at planting, farmers might anticipate higher yields and thus might apply more nitrogen. However, excessive precipitation during April through June results in wet fields, and hence may limit after-planting nitrogen applications. The empirical results indicate that nitrogen application rates declined when rainfall increased during the spring months.

Herbicide Use and Cost

More than 97 percent of corn fields in the 10 States were treated with herbicides. Fields not treated with herbicides were excluded from the analysis because they had no information on some herbicide practices. A preliminary analysis indicated that farmers' yield expectations (represented by actual yields) had little effect on herbicide or insecticide use. Consequently, the observations which had no yield information were included in the analysis of pesticide use. In total, there were 9,148 observations included in the analysis of herbicide use. The average herbicide use was 3.15 pounds per acre and the average cost was $18.38 per acre.

The empirical results were summarized in table C-2. The R^2 is around 10 percent, which is much lower than the goodness-of-fit of the nitrogen use equation, indicating a critical need to collect information on pest management practices, such as target pest and economic thresholds, in order to improve our understanding of pesticide use patterns in corn production.

Conventional-till with the moldboard plow received fewer pounds of herbicides and incurred lower herbicide costs

[4] In nitrogen applications, broadcast includes air and ground broadcast, chemigation, and injection; band includes in furrow and banded in.

than the other three tillage systems, at the 5 percent significance level. Conventional-till without the moldboard plow, mulch-till, and no-till received a similar amount of herbicides, but no-till incurred higher herbicide costs, at the 5 percent significance level. Compared with other tillage systems, no-till tends to use more expensive, non-selective pre-plant, and post-emergence herbicides. Because the majority of corn farmers who practiced conventional tillage did not use the moldboard plow, one should not come to the conclusion that switching from conventional tillage to conservation tillage would always increase herbicide use.

Mechanical cultivation for weed control was a substitute for herbicides. Each cultivation was found to reduce herbicide use by nearly 0.17 pounds and reduce herbicide costs by $0.65 per acre. It should be pointed out that herbicide costs include only material costs, not application costs. The custom rate for application (excluding materials) was estimated to be $4 per acre and the rate for row crop cultivation was $5 per acre for the North Central region in 1993 (11). At these costs, herbicides appeared to be more economical than mechanical cultivation in controlling weeds.

Corn farmers in the 10 States were categorized by whether or not they applied herbicides only before planting, whether herbicides were applied by farmers or custom applicators, and whether they applied herbicides by broadcast or band.[5] A priori expectations were: farmers who completed herbicide applications before planting tend to use higher rates than farmers who applied herbicides at or after planting; band application rates are substantially lower than broadcast rates; and farmers may or may not apply higher rates than custom applicators.

Farmers who completed herbicide applications before planting applied herbicides at a higher rate, 0.28 pounds, but incurred a lower cost of $1.76 per acre than other farmers at the 1 percent significance level. Most of the herbicides applied before planting have pre-emergence activity, and are less expensive because they usually are older materials with expired patents. Alachlor, atrazine, and metolachlor, the three most commonly used herbicides, are prime examples.

Most post-emergence herbicides are relatively new in the market, more expensive, and applied at much lower rates than pre-emergence herbicides. Farmers who banded herbicides used 0.61 pounds less and incurred a lower cost of $3.14 per acre than farmers who broadcast herbicides, significant at the 1 percent level. Farmers applied herbicides at a slightly lower rate and incurred a slightly lower cost per acre, compared with custom applicators (significant at the 10 percent level).

Eight interactive dummy variables were created to examine the effects of cropping sequences and program participation. The base variable was 3-year corn with program participation. Among the fields enrolled in the program, no significant differences in herbicide use could be found among fields in 3-year corn, 2-year corn, and corn/soybean. Among the fields that were not enrolled in the program, the only significant difference in herbicide use was between 3- and 2-year corn. The results suggest that crop rotations have limited effect on weed control and that weed control is not a primary objective of crop rotations.

Compared with non-participants, participants of the feedgrain program significantly increased herbicide use and costs among some cropping sequences: an increase of 0.36 pounds and $2.14 per acre among 2-year corn fields; and an increase of 0.12 pounds and $0.73 per acre among corn/soybean fields. No significant differences were found for the fields that were in 3-year corn or in corn/other sequence. In sum, the empirical results provided some support to the view that commodity programs contributed to greater herbicide use in corn production.

Use of a fall cover crop significantly reduced herbicide cost, but not herbicide use. Seeding rates reflect crop densities and higher seeding rates significantly increased herbicide use and costs. Herbicide use increased with temperature, suggesting a positive relationship between weed population and temperature. It should be noted again that temperature may also capture the effects of some regional factors that are not included in the model.

Insecticide Treatment, Use, and Cost

Among the 9,289 observations analyzed in the 10 States, 2,413 fields (26 percent) were treated with insecticides. Some production practices, such as crop rotations, affect insecticide use and costs in two ways. A switch from continuous corn to other patterns (such as corn/soybean) effectively reduces corn rootworm larvae populations, a major corn insect. Consequently, the chance of needing insecticide treatment (or the percent of acres treated) is greatly reduced. Further, the application rate is lowered if treatments are made.

To separate the effects on the percent of acres treated and the application rate, two analyses were conducted. The first analysis investigated factors that determine whether or not a field was treated with insecticides. Because the value of the dependent variable was either 0 (not treated) or 1 (treated), the model of qualitative choice (probit model) was employed in the first analysis. The second analysis identified and quantified factors that influence insecticide use and costs among fields that were treated with insecticides. The empirical results are reported in tables C-3 and C-4.

Treatment or No Treatment

Cropping sequences are the predominant determinants of insecticide use in corn production. The empirical results suggest that program participation increased the chance of having insecticide treatments by almost 37 percent on 3-year corn (significant at the 1 percent level), and by 19 percent on 2-year corn (significant at the 5 percent level).

[5] In pesticide applications, broadcast includes air and ground broadcast, chemigation, and directed spray; band includes in furrow and banded in.

Table C-3. Treatment or no treatment with insecticides probit, qualitative choice model

	Coeff.	t-value
Constant	3.50	-6.32
Convent-till with MBP	base variable	
Convent-till w/o MBP	0.20	4.21
Mulch-till	0.01	0.15
No-till	0.15	2.17
3-year Corn & Program	base variable	
2-year & Program	-0.33	-5.63
Soybean/Corn & Program	-1.67	-35.65
Other/Corn & Program	-1.31	-19.86
3-year Corn & No Program	-0.37	-5.24
2-year Corn & No Program	-0.52	-6.46
Soybean/Corn & No Program	-1.62	-26.17
Other/Corn & No Program	-1.27	-14.39
Seeding Rate	0.03	4.61
Temperature	0.05	5.74
Early Season Maturity	0.06	1.03
Medium Maturity	0.24	5.00
Full Season Maturity	base variable	
Cover Crop	-0.02	-0.19
Year 1990	0.15	3.94
Year 1991	-0.18	-3.02
Maddala R-Square	0.20	

Table C-4. Factors Affecting Insecticide Use and Cost

	Use		Cost	
	Coeff.	t-value	Coeff.	t-value
	lbs/ac		$/ac	
Constant	0.98	2.41	-1.57	-0.41
Convent-till with MBP	base variable			
Convent-till w/o MBP	-0.04	-1.34	-0.18	-0.66
Mulch-till	-0.07	-2.15	-0.46	-1.50
No-till	-0.17	-3.91	-0.67	-1.63
3-year Corn	base variable			
2-Year Corn	-0.05	-1.97	-0.38	-1.57
Corn/Soybean	-0.11	-4.11	-1.36	-5.54
Corn/Other	-0.07	-1.63	-0.44	-1.20
Program Participation	-0.03	-1.23	-0.15	-0.69
Pre-Plant Applications	0.02	0.37	-0.02	-0.05
Band Applications	0.19	6.55	2.01	7.52
Farmer Self Applications	-0.06	-1.59	0.03	0.08
Early Season Maturity	-0.01	-0.22	0.19	0.55
Medium Maturity	0.02	0.07	0.45	1.51
Full Season Maturity	base variable			
Cover Crop	0.00	0.03	-1.07	-2.46
Seeding Rate	0.02	4.28	0.24	6.35
Temperature	-0.01	-1.16	0.09	1.65
Year 1990	0.11	4.30	0.01	0.06
Year 1991	0.05	1.24	-0.49	-1.34
R-Square	0.07		0.08	
Adj. R-Square	0.07		0.07	

However, participation in the feedgrain program did not directly affect the chance of having insecticide treatments on the corn acres that followed a crop other than corn. When the cropping sequence was switched from 3-year corn to 2-year corn, the chance of having insecticide treatments was reduced by 33 percent among program participants and was by 15 percent among the acres not enrolled in the program.

Rotating corn with another crop provides effective rootworm control, thus greatly reducing the need for insecticide applications. This effect is best exemplified by the corn/soybean cropping sequence, which reduced the chance of having insecticide treatments by at least 125 percent when compared with 3-year corn, and by at least 100 percent when compared with 2-year corn. When corn followed a crop other than corn or soybeans, insecticide treatments were also greatly reduced. These findings testify to the statement by Pimentel et al (34) that continuous cropping sequence has drastically increased insecticide use as well as yield losses to pests in corn production.

Tillage practices influenced whether or not a field was treated with insecticides. Conventional-till with the moldboard plow and mulch-till had a smaller percent of acres treated with insecticides (significant at the 5 percent level), while no significant difference could be found between conventional-till without the moldboard plow and no-till.

Higher seeding rates, higher temperature, and a shorter maturity length were also found to significantly increase the chance of having insecticide treatments among corn acres. Insect problems varied from year to year, thus significantly affecting the percent of corn acres being treated with insecticides.

Use and Cost

On the average, 0.25 pounds of insecticides at a cost of $2.74 per acre were applied to all the non-irrigated corn acres in the 10 States. On the treated acres, the average application rate was around one pound per acre at a cost of $11.20.

Reducing the number of years of corn in the cropping sequence not only greatly reduced the chance of having insecticide treatments, but also significantly reduced the application rate. Among the four cropping sequences, the corn/soybean pattern had the lowest insecticide application rate and costs: 0.11 pounds and $1.36 per acre lower than the 3-year corn; and 0.06 pounds and $0.98 per acre lower than the 2-year corn. Feedgrain program participation did not directly affect the insecticide application rate and costs.

Since cropping sequences play a key role in determining insecticide use, commodity programs may have an indirect effect on insecticide use if it also influences cropping patterns. Conventional wisdom suggests that commodity programs impose inflexibility in cropping patterns, while Gargiulo (16) provides empirical evidence showing that commodity programs actually increase crop diversity and thus reduces insecticide use. Obviously, future research is warranted to improve our understanding of the farmers' rotation decisions.

When compared with conventional-till with the moldboard plow, no-till had higher percent of acres being treated with insecticides but lower application rates on treated acres. Therefore, a switch from conventional-till with the moldboard plow to no-till may or may not increase insecticide use, depending on other practices, such as cropping sequences. The empirical results also suggest no-till received significantly lower rates of insecticides than other tillage systems. Mulch-till acres were treated with signifi-

cantly lower rates of insecticides than conventional-till with the moldboard plow but not conventional-till without the moldboard plow. Finally, the use of the moldboard plow in the conventional tillage systems did not significantly influence insecticide application rates. Additionally, no significant differences in per-acre treatment costs could be found among the four tillage practices, at the 5 percent significance level.

Insecticide application rates and costs were affected significantly by application methods. Contrary to the findings on herbicide use, band applications had higher insecticide application rates than broadcast applications. This can be explained by the fact that rootworm larvae is the predominant insect problem in corn, which is usually controlled by banded applications. Farmers who broadcast insecticides to treat cutworms, European corn borer, and mites used insecticides which are applied at lower rates. Insecticide application rate and cost also increased with seeding rates and varied from year to year.

Conclusions

An important step towards reducing chemical use in U.S. agricultural production is to identify less chemical-intensive production practices and measure their effects. In this article we summarized the literature on the effects of some production practices and government programs on agrichemical use. Then we compared the results reported in the literature with the results of an analysis of field-level data collected through the USDA Cropping Practices Surveys on corn during 1990 through 1992. The empirical results provide some insights into chemical use in corn production.

Both nitrogen and herbicide use, measured in pounds per acre of active ingredients applied, can be substantially reduced by switching from broadcast to band applications and from pre-plant to after-plant applications. However, there are economic costs associated with these changes. Timing and method of applications have little influence on insecticide use.

Crop rotations are the most effective means for reducing insecticide use in corn production. A switch from continuous corn to corn/soybean drastically reduces the percent of corn acres treated with insecticides and lowers the insecticide application rates on treated acres. Also, moving from 3-year corn to 2-year corn is effective in reducing insect problems. The higher profit for corn production relative to that of other crops and the need for corn in an integrated crop/livestock operation are two of the major barriers to crop diversity. The empirical results support the view that crop rotations have limited effect on weed control. Crop rotations also do not reduce nitrogen use in corn production probably because farmers do not give credit to residual nitrogen from the previous soybean crop.

A switch from conventional tillage (with or without the moldboard plow) to conservation tillage (mulch- or no-till) does not necessarily increase agrichemical use. Our empirical results suggest that nitrogen use does not vary across tillage systems. A switch from conventional-till with the moldboard plow to conservation tillage does increase herbicide use. However, conventional-till without the moldboard plow uses herbicides at a rate similar to conservation tillage. Thus, a shift from conventional tillage without the moldboard plow to conservation tillage will not affect herbicide use. Similarly, moving away from conventional tillage to conservation tillage does not necessarily increase insecticide use.

The empirical results of the study provides some support for the view that participation in the feedgrain program increases herbicide and insecticide use in corn production. Herbicide use in the 2-year corn and corn/soybean sequences increased with program participation. Program participation does increase the percent of continuous corn acres (but not other cropping sequences) being treated with insecticides. Participation in the feedgrain program does not directly influence the insecticide application rates across all cropping sequences. However, program participation may influence cropping sequences and thus affect insecticide use in corn production. To improve our understanding of the role of commodity programs in insecticide use, we need to study the farmers' decision-making on crop rotations.

References

1. Blackwell, M. and A. Pagoulatos. "The Econometrics of Damage Control: Comment." *Amer. J. Agri. Econ.* 74(1992):1040-1044.

2. Bull, L. Residue and Tillage Systems for Field Crops. Staff Report AGES 9310, USDA/ERS/RTD. July 1993.

3. Carlson, G., M. Cochran, M. Marra, and D. Zilberman. "Agricultural Resource Economics and the Environment," *Review of Agri. Econ.*, 14(1992):313-326.

4. Committee on the Role of Alternative Farming Methods in Modern Production Agriculture, *Alternative Agriculture*, Washington D.C., National Academy Press, 1989.

5. Cook, R.J. "Root Health: Importance and Relationship to Farming Practices." in *Organic Farming: Current Technology and Its Role in a Sustainable Agriculture*, Eds. Bezdicek, D.E. and J.F. Power, Special Pub. NO. 46, Midson, WI: American Society of Agronomy, Crop Science Society of America, Soil Science of America. 1984.

6. Cook, R.J. "Wheat Management Systems in the Pacific Northwest," *Plant Disease*, 70(1986):894-898.

7. Curl E.A. "Control of Plant Disease by Crop Rotation," *Botany Review*, 29(1963):413-418.

8. Crosson, P. *Conservation Tillage and Conventional Tillage: A Comparative Assessment.* Soil Conservation Society of America, Ankeny, Iowa, 1981.

9. Daberkow, S.G. and K.H. Reichelderfer. "Low-Input Agriculture: Trends, Goals, and Prospects for Input Use." *Amer. J. Agri. Econ.* 70(1988):1159-1166.

10. Dickey, E.C., P.J. Jasa, B.J. Dolesh, L.A. Brown and S.K. Rockwell. "Conservation Tillage: Perceived and Actual Use," *J. of Soil and Water Conservation*, Nov-Dec., 1987:431-434.

11. Doane Information Service. *Doane's Agricultural Report: Reference Volume*. St. Louis, MO. 1993.

12. DPRA Inc. *AGCHEMPRICE: Current USA Prices of Non-Fertilizer Agricultural Chemicals*. various issues. Manhattan KS.

13. Duffy, M. and M. Hanthorn. *Returns to Corn and Soybean Tillage Practices*. AER-508, USDA/ERS, January 1984.

14. Ek, C.W. *Farm Program Flexibility: An Analysis of Triple Base Option*. Congressional Budget Office, 1989.

15. Feinerman, E., E.K. Choi and S.R. Johnson. "Uncertainty and Split Nitrogen Application in Corn Production." *Amer. J. Agri. Econ.*, 72(1990):975-984.

16. Gargiulo, C.A. *Demand for Insecticides in Corn: Effects of Rotations and Government Programs*, Ph.D. dissertation, Dept. of Agri. and Resource Econ., North Carolina State University, Raleigh, NC, 1992.

17. Goldstein, W.A. and D.L. Young. "An Agronomic and Economic Comparison of a Conventional and a Low-Input Cropping System in the Palouse," *Amer. J. Alt. Agri.*, 2(1987):51-56.

18. Heady, E.O. and M.H. Yet. "National and Regional Demand for Fertilizer." *J. Farm Economics*, 41(1961):332-348.

19. Heichel, G.H. "Legumes as a Source of Nitrogen in Conservation Tillage Systems," in *The Role of Legumes in Conservation Tillage System*, Ed. Power, J.F., Ankeny, Iowa: Soil Conservation of America, 1987.

20. Hertel, T.W., M.E. Tsigas, and P.V. Preckel. *An Economic Assessment of the Freeze on Program Yields*, Staff Report No. 9066. USDA/ERS/RTD. December 1990.

21. House of Representatives. *Low-Input Farming Systems: Benefits and Barriers*. 74th Report by the Committee on Government Operations. U.S. Government Printing Office, Washington D.C. 1989.

22. Kapusta, G. "Post-Emerge herbicide programs proliferate." *Solutions*, May/June, 1992:22 and 26.

23. Lathwell, P.J., D.R. Bouldin, and W.S. Reid. "Effects of Nitrogen Fertilizer Application in Agriculture." *Relationship of Agriculture to Soil and Water Pollution*, Proceedings of Cornell University Conference on Agricultural Waste Management, Syracuse, New York, 1970.

24. Lin, B.H., L. Hansen, S. Daberkow and M. Dreitzer. "Substitutability of Crop Rotations for Agrichemicals: Preliminary Results." *Agricultural Resources: Input Situation and Outlook Report*, AR-24, ERS/USDA, Oct. 1991. pp. 24-29.

25. Lockeretz, W. "Replicability in Agricultural Field Experiments." *Amer. J. Alt. Agri.*, 8(1993):50.

26. Logan, T.J., J.M. Davidson, J.L. Baker, and M.R. Overcash. *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides*. Chelsea, MI. Lewis Publishers, Inc. 1987.

27. Marshall, D. "Crop Diversity for Plant Pathogen Control," in *Handbook of Pest Management in Agriculture*, Ed. Pimentel, D., 2nd edition, Vol. 1, Boca Raton, Florida. CRC Press Inc. 1991.

28. Miranowski, J.A. *The Demand for Agricultural Crop Chemicals Under Alternative Farm Program and Pollution Control Solutions*. Ph.D. dissertation, Harvard University, 1975.

29. Mjelde, J.W., M.E. Rister, R.C. Griffin, and L.A. Lippke. "Are Government Programs Influencing Input Intensity," *Review of Agri. Econ.*, 14(1992):227-239.

30. Ogg, C. "The Welfare Effects of Erosion Control, Banning Pesticides, and Limiting Fertilizer Application in the Corn Belt: Comment." *Amer. J. Agri. Econ.*, 60(1978):559.

31. Ogg, C.W. "Farm Price Distortions, Chemical Use, and the Environment," *J. Soil and Water Conservation*, January-February, 1990:45-47.

32. Osteen, C.D. and P.I. Szmedra. Agricultural Pesticide Use Trends and Policy Issues. AER #622, USDA/ERS, September 1989.

33. Pimentel, D., G. Berardi, and S. Fast. "Energy Efficiencies of Farming Wheat, Corn, and Potatoes Organically," *Organic Farming: Current Technology and Its Role in a Sustainable Agriculture* Eds. Bezdicek, D.E. and J.F. Power, Special Pub. NO. 46, Midson, WI: American Society of Agronomy, Crop Science Society of America, Soil Science of America. 1984.

34. Pimentel, D., C. Shoemaker, E.L. DaDue, R.B. Rovinsky, and N.P. Russell. *Alternative for Reducing Insecticides on Cotton and Corn: Economic and Environmental Impacts*. EPA-600/5-79-007a. Environmental Research Laboratory, EPA, Athens, GA. 1979.

35. Power, J.F. "Legumes: Their Potential Role in Agricultural Production," *Amer. J. Alt. Agri.*, 2(1987):69-73.

36. Roberts, D.A. "Using Nonchemical Methods to Control Diseases of Plants," in *Handbook of Pest Management in Agriculture*, Ed. Pimentel, D., 2nd edition, Vol. 1, Boca Raton, Florida. CRC Press Inc. 1991.

37. Sailer, R.I. "Extent of Biological and Cultural Control of Insect Pests of Crops," in *Handbook of Pest Management in Agriculture*, Ed. Pimentel, D., 2nd edition, Vol. 2, Boca Raton, Florida. CRC Press Inc. 1991.

38. Shoemaker, R., M. Anderson, and J. Hrubovcak. *U.S. Farm Programs and Agricultural Resources*, AIB #614, USDA/ERS. September 1990.

39. Slife, F.W. "Environmental Control of Weeds," in *Handbook of Pest Management in Agriculture*, Ed. Pimentel, D., 2nd edition, Vol. 1, Boca Raton, Florida.CRC Press Inc. 1991.

40. USDA, ERS. *Agricultural Resources: Inputs Situation and Outlook Report*. AR-3, August 1986. p.25.

41. USDA, ERS. *Agricultural Resources: Inputs Situation and Outlook Report*. AR-28, October 1992. p.8.

42. USDA, ERS. *Agricultural Resources: Inputs Situation and Outlook Report*. AR-29, February, 1993. p.22.

43. Voss, R.D. and W.D. Shrader. "Rotation Effects and Legume Sources of Nitrogen for Corn." in *Organic Farming: Current Technology and Its Role in a Sustainable Agriculture*, Eds. Bezdicek, D.E. and J.F. Power, Special Pub. NO. 46, Midson, WI: American Society of Agronomy, Crop Science Society of America, Soil Science of America. 1984.

44. Young, D.L. and K.M. Painter. "Farm Program Impacts on Incentives for Green Manure Rotations," *Amer. J. Alt. Agri.*, 5(1990):99-105.

45. Zimdahl, R.L. "Extent of Mechanical, Cultural, and Other Nonchemical Methods of Weed Control," in *Handbook of Pest Management in Agriculture*, Ed. Pimentel, D., 2nd edition, Vol. 2, Boca Raton, Florida. CRC Press Inc. 1991

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Appendix table 1--Tillage systems used in winter wheat production, 1993 1/

Category	CO	ID	IL	KS	MO	MT	NE	OH	OK	OR	SD	TX	WA	Area 2/
Harvested acres (1000)	2550	850	1550	11300	1400	2500	2100	1000	5500	860	1400	3700	2500	37210
	Percent of acres 3/													
Highly erodible land	54	56	38	29	45	59	30	13	20	45	32	19	55	34
Tillage system:														
Conv/w mbd plow 4/	nr	11	id	6	id	1	6	4	10	36	id	nr	6	6
Conv/wo mbd plow 5/	75	75	61	76	66	83	79	69	85	44	68	85	69	76
Mulch-till 6/	25	7	9	16	8	15	12	4	5	18	25	13	22	14
No-till 7/	nr	[illegible]	28	2	24	id	2	23	nr	id	5	1	4	4
Residue remaining after planting:	Percent of soil surface covered													
Conv/w mbd plow	nr	2	id	2	id	id	2	1	1	2	id	nr	2	2
Conv/wo mbd plow	16	9	16	13	17	14	15	14	12	15	18	11	14	13
Mulch-till	40	45	39	35	39	40	37	35	43	37	42	40	42	39
No-till	nr	63	56	63	53	id	35	52	nr	id	58	72	33	54
Average	22	15	29	17	27	19	17	23	13	14	26	16	20	18
	Number													
Hours per acre:														
Conv/w mbd plow	nr	.5	id	.5	id	id	.7	.8	.7	.8	id	nr	.7	.7
Conv/wo mbd plow	.4	.5	.3	.5	.3	.4	.6	.4	.5	.5	.4	.5	.6	.5
Mulch-till	.2	.4	.3	.3	.3	.2	.4	.4	.3	.5	.2	.3	.2	.3
No-till	nr	.1	.1	.1	.1	id	.1	.1	nr	id	.1	.1	.1	.1
Average	.3	.4	.2	.5	.3	.3	.5	.3	.5	.6	.3	.5	.5	.4
Times over field:														
Conv/w mbd plow	nr	4.4	id	5.8	id	id	6.5	3.3	5.9	5.7	id	nr	5.1	5.6
Conv/wo mbd plow	5.3	3.9	2.6	5.3	2.5	4.8	5.6	2.5	5.2	4.4	4.7	4.8	6.2	5.0
Mulch-till	4.0	3.5	2.3	5.0	2.3	3.1	3.5	2.4	3.8	3.9	3.8	3.8	3.9	4.1
No-till	nr	1.0	1.0	1.0	1.1	id	1.0	1.0	nr	id	1.0	1.0	1.0	1.0
Average	5.0	3.7	2.1	5.2	2.2	4.5	5.3	2.2	5.2	4.7	4.2	4.6	5.4	4.7

id = Insufficient data. nr = None reported.

1/ Preliminary. 2/ Arkansas and Indiana not included in 1993. 3/ May not add to 100 due to rounding. 4/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 5/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 6/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 7/ No-tillage--no residue-incorporating tillage operations performed prior to planting; does allow passes of non-tillage implements, such as stalk choppers.

Appendix table 2--Tillage systems used in fall potato production, 1992

Category	CO	ID	ME	MI	MN	NY 1/	ND	OR	PA	WA	WI	Area
Planted acres (1000) 2/	66.5	380	81	37	71	21	145	45	20	125	66	1,057.5
	Percent of acres 3/											
Highly erodible land	83	45	20	8	9	26	11	45	19	40	4	33
Tillage system:												
Conv/w mbd plow 4/	25	24	45	86	25	65	32	47	96	28	68	35
Conv/wo mbd plow 5/	69	75	36	14	65	23	47	50	3	59	17	56
Mulch-till 6/	6	1	16	nr	10	9	21	3	nr	13	11	8
No-till 7/	nr	nr	3	nr	nr	id	nr	nr	id	nr	4	1
Residue remaining	Percent of soil surface covered											
after planting:												
Conv/w mbd plow	1	2	2	2	3	2	2	1	2	2	2	2
Conv/wo mbd plow	10	8	9	13	19	12	16	5	29	11	10	10
Mulch-till	33	35	42	nr	36	68	42	51	nr	37	38	40
No-till	nr	nr	72	nr	nr	id	nr	nr	id	nr	32	47
Average	9	6	13	3	17	11	17	4	4	12	9	10
	Number											
Hours per acre:												
Conv/w mbd plow	1.0	.8	1.0	.8	.6	.9	.4	1.1	1.1	1.0	.6	.8
Conv/wo mbd plow	.8	.8	.8	.8	.5	.8	.3	1.4	1.3	.9	.5	.7
Mulch-till	.8	.4	.7	nr	.3	.2	.2	.5	nr	.6	.2	.4
No-till	nr	nr	.4	nr	nr	id	nr	nr	id	nr	.2	.2
Average	.8	.8	.9	.8	.5	.8	.3	1.2	1.1	.9	.5	.7
Times over field:												
Conv/w mbd plow	4.7	4.1	3.6	3.7	3.7	2.8	3.4	4.6	3.4	4.5	2.9	3.8
Conv/wo mbd plow	4.5	4.5	3.3	3.3	4.1	3.8	3.8	5.0	3.0	4.4	3.1	4.3
Mulch-till	3.3	1.7	2.5	nr	3.3	2.0	2.6	2.0	nr	3.0	2.6	2.7
No-till	nr	nr	1.0	nr	nr	id	nr	nr	id	nr	1.0	1.0
Average	4.4	4.4	3.3	3.7	3.9	2.9	3.4	4.7	3.4	4.2	2.8	4.0

id = Insufficient data. nr = None reported.

1/ Excludes Long Island. 2/ Preliminary. 3/ May not add to 100 due to rounding. 4/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 5/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 6/ Mulch-tillage--system that has 30 percent or greater remaining residue after planting and is not a no-till system. 7/ No-tillage--no residue-incorporating tillage operations performed prior to planting; does allow passes of non-tillage implements, such as stalk choppers.

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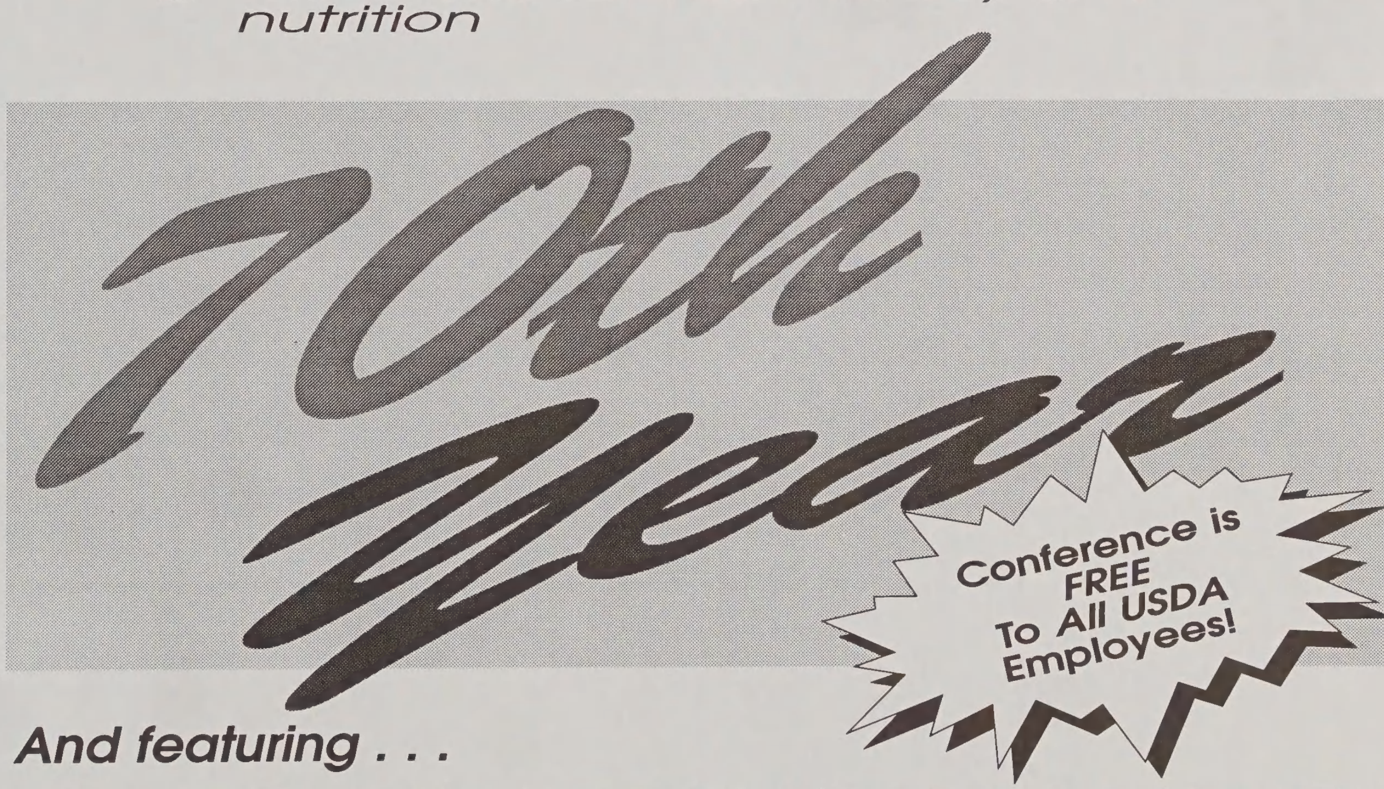

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